NATURE Unhooked



MDC DISCOVER nature SCHOOLS

Teacher Guide

NATURE Unhooked

Discover Nature Schools Middle School Instructional Unit

Teacher Guide

Missouri Department of Conservation

On the cover: An American white pelican nets an Asian carp for a snack. Photo by Danny Brown.

In this guide, students will set out on an aquatic quest, discovering the incredible journey of the water cycle as well as the structures and properties of water. Students will dive into energy flow of food chains and webs, all the while gaining an appreciation for aquatic biodiversity and human interactions within these systems.

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The Missouri Department of Conservation and the Missouri Department of Natural Resources have teamed up to bring you an all-new middle school science unit: Discover Nature Schools — *Nature Unhooked*.

The mission of the Conservation Department is to protect and manage the fish, forest, and wildlife resources of the state; and to facilitate and provide opportunities for all citizens to use, enjoy, and learn about these resources.

The mission of the Department of Natural Resources is to protect our air, land, and water; to preserve our unique natural and historic places; and to provide recreational and learning opportunities for everyone.

Together, our organizations cover the breadth of conservation and natural resource issues in the state. As part of our missions, we want to encourage students to be knowledgeable about our natural world and how we as humans are interdependent with and connected to nature.

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Discover Nature Schools

Discover Nature Schools (DNS) is a superior science and conservation education program. Instructional units constitute the backbone of the DNS program and include exciting and engaging inquiry-based activities designed to bring students in grades Pre-K–12 outdoors and closer to nature.

Units include colorful and engaging student books as well as teacher guides with activities designed to meet Missouri Department of Elementary and Secondary Education (DESE) state standards as well as the Next Generation Science Standards (NGSS). Use of science notebooks by students is an important and integrated component.

Lesson plans guide teachers toward utilizing immediate school grounds as important resources for student learning. At the heart of the DNS program is the belief that the more students equate the outdoors with learning, the more comfortable they become outdoors and the more in tune and familiar they become with outdoor environments. As students become more comfortable and familiar with learning and documenting outdoor experiences, the more they begin to think and act like observant scientists sensitive to and inquisitive about changes in outdoor environments.

Student books, teacher guides, and student science notebooks (as well as training in their use) are available to all Missouri educators at no charge. However, teachers who enroll formally in the DNS program are eligible for additional resources including grant opportunities for field experiences and classroom materials to support each instructional unit. More information about the DNS program as well as other resources and opportunities for teachers may be found on the Teacher Portal at **mdc.mo.gov/teachers**.

DNS Units

Nature Revealed — Preschool
Nature Unfolds — Kindergarten–Grade 2
Nature Unleashed: The Untamed World of Missouri Ponds, Forests, and Prairies — Grades 3–5
Nature Unhooked — Grades 6–8
Nature Unbound: The Impact of Ecology on Missouri and the World — Grades 9–12

Nature Unhooked

Unit Overview

Nature Unhooked is a unit designed to be taught at the 6–8 grade level. Each activity meets at least one Next Generation Science Standard at the middle school level. *Nature Unhooked* activities are designed to be adapted easily by teachers to meet student needs. Most activities in this unit get students outdoors and exploring, investigating, and asking questions about immediate areas around their school. However, a variety of activities have been included to provide more tools to meet diverse learning styles of students and to allow for different teaching styles and preferences. Activities for teaching each chapter in the student book are provided (see Activity Components for details) as well as a chart showing alignment with the Next Generation Science Standards.

Detailed teaching strategies are provided to guide teachers through an understanding of the content matter and of how to teach the content matter. Science notebooks are a key component of every activity, and science notebooks designed specifically for use with the *Nature Unhooked* unit are available for every student. This teacher guide contains introductory materials addressing the integration of science notebooks, scientific inquiry, and field investigations into the activities.

Nature Unhooked student books and science notebooks are issued for every student. These publications may be ordered at no charge through the Teacher Portal at **mdc.mo.gov/teachers**. Further, the student book may be downloaded so that teachers and students may upload it to Chromebooks and other electronic notebooks. The Teacher Portal provides a number of resources related to *Nature Unhooked*. After creating an account, teachers may download the curricular resources, full-color materials, and extensions; access grant information; register for professional development; view related video segments; and interact with other teachers and share resources and ideas through an online bulletin board.

Chapter Introductions

The chapter introduction page includes a list of activities for that chapter, associated Missouri Learning Standards and Next Generation Science Standards, estimated time, and vocabulary list. The estimated time section suggests how much time each chapter may take if all activities are conducted. Actual time will be affected by the following factors:

- grade level
- daily schedule of the school
- need for review of previous learning based on the extent of student prior knowledge
- need for reteaching based on the results of formative assessments
- additional resources/knowledge of teacher
- time allotted for group presentations based on class size
- time allotted for cooperative learning activities
- number of activities given as homework rather than completed as class activities
- availability of resources for student use

Activity Components

Estimated Time — The approximate time needed to conduct the activity.
Learning Standards — Codes for the Missouri Learning Standards and the Next Generation Science Standards. Refer to the chapter introduction page for more details.
Objectives — Specific things students will be able to do after completing all parts of the activity. Activity objectives are based on the performance expectations of the Next Generation Science Standard(s) met in the activity.
Teacher Preparation — Information to help the teacher prepare for the activity. It may contain additional content information for the teacher, tips or best practices for conducting the activity, suggestions for what the teacher should do in advance of class, and suggested references for additional background information.
Materials — Items and equipment needed to conduct the activity.
Procedure — Step-by-step list of instructions to help teachers guide students through the hands-on activity. Q&A sections are intended to probe student learning, provoke thought and connection, and guide students toward achieving activity objectives. Q&A sections also provide teachers opportunities for formative assessment.
Wrap-up/Assessment — Final procedures designed to help students reach conclusions, process new information and concepts, complete performance expectations of the standards, achieve activity objectives, and reflect on their learning. Can be recorded in student science notebooks; often include suggestions for students to prepare and present their discoveries, data, and other evidence of learning; and provide opportunities for formative or summative assessment.
Resources — Internet-based and other media providing more background information for the teacher, multimedia demonstrations, and sources for student research.
Extension — Suggestions for students to extend their explorations in additional or different ways. Extensions include ideas for teaching and learning in different styles and subjects, and provide additional opportunities for assessment.
Science Notebook Pages — Pages are marked with a . These pages are also included in the *Nature Unhooked Science Notebook*, available to each student.
Cross-Curricular/Differentiated Instruction — This section provides differentiated instruction techniques for diverse learners as well as opportunities to reinforce lesson plan objectives through a multidisciplinary approach.
Taking It Home — Tied with the "Keep Discovering" feature in the *Nature Unhooked Student Book*. This sections provides opportunities for further student exploration and for family involvement. When applicable, citizen science connections and outdoor skill or involvement opportunities are added to enrich depth of knowledge.

Outdoor Learning

Outdoor learning is an integral component of *Nature Unhooked,* and most activities are designed to be conducted in the schoolyard or beyond. Students should become comfortable outdoors working alone or in groups and should regard the schoolyard and accessible areas around the school as their natural classroom and laboratory. Students should also respect the boundaries and rules set by teachers while working in these outdoor natural classrooms/laboratories.

Preparatory walks prior to bringing students outdoors are suggested for teachers to familiarize themselves with the schoolyard and identify areas that will work best for the activities. These preparatory walks also help teachers determine if there are any objects or areas to avoid during *Nature Unhooked* activities, such as openings in fences; areas beyond school property; areas that are slippery, muddy, or wet from recent storms; maintenance activities; etc. It is advisable for teachers to help students recognize and avoid poison ivy.

Extreme weather aside, outdoor exploration and observation during light rain and snow can provide students with surprising and unusual information about their schoolyard ecosystem and offer insights into new and interesting interactions among living things and nonliving weather factors (water, air temperature, wind). Well-established clothing and behavior guidelines will reduce or eliminate any potential hazards to students while outdoors in any weather.

If multiple teachers are conducting *Nature Unhooked*, communication between teachers will be essential to share equipment and resources, to avoid multiple classes using the same areas at the same time, and to avoid disturbing study areas. Teachers may wish to identify different areas of the schoolyard for their classes.

Wrap-up/Assessment Strategies

Nature Unhooked offers four models of assessment for teacher use.

- **During Activity Assessments:** listed in teacher guide as boldface Q&A
- **Science Notebook Student Self-Scoring Rubric:** found in back of student science notebook. This assessment strategy allows for student self-scoring of science notebook entries
- **End-of-Chapter Assessments:** to be used as either formative or chapter summative assessments.
- **Unit Pre- and Post-test:** found in Appendix of teacher guide.

For suggested use of each assessment model, see *Unit Assessment Strategies* in Appendix.

Exit Note

Ask students to write an exit note that includes a question they still have about what they learned in the activity and/or a question they would like to investigate. Exit notes can be written on a piece of paper and placed in an "Exit Note" box placed near the classroom door, written on a sticky note and stuck to a designated spot on the wall near the door, written on a piece of paper and stuck to a self-stick bulletin board, etc. Determine whether student submissions should remain anonymous. Exit notes should be reviewed to determine what concepts need to be retaught before moving on to the next activity.

Group Report with Presentation

Divide the class into groups of four students. Number each group's team members 1–4. Within each group, give each group one or more questions to answer related to the activity. Activity objectives and the questions students are being asked will determine the length of time required for this strategy. Explain that all group members should be prepared to give a brief presentation of the answers to their question(s). Roll a dice for each group to determine who will give the presentation for the group.

Popcorn Balls or Snowballs

Prepare question(s) in advance or pose one based on any problem areas arising during the activity. Ask students to answer one multiple choice question and have each student write an explanation of his or her answer choice on a piece of paper. Instruct students to crumble up their paper like a snowball or ball of popcorn. When ready, have students toss their snowballs/popcorn balls to other students. Repeat tosses at least three times to ensure balls of paper are thoroughly mixed up. Ask a student to read the answer and explanation on his or her paper. Call upon other students to do the same before asking students if they agree or not with the answer selected and explanation given. Discuss as needed.

Think-Pair-Share

Assign a question or problem for the class. Allow time for individuals to think silently about it, and then have students pair up and exchange thoughts. Have the pairs share their responses with the class.

Open-ended Inquiry Questions

Ask a student an open-ended inquiry question. Ask the rest of the class whether they agree or disagree with the student's answer and explain their reasoning. Ask additional questions and discuss as needed.

Summary

At the completion of an activity, have students summarize what they learned. Students can record this information in their science notebooks by writing and/or drawing. Teachers should collect science notebooks. Teachers can then determine what students really understand and determine content that needs to be retaught. The content of students' science notebooks can be graded or not depending on teacher's preference for each activity.

Correlations to the Next Generation Science Standards and the Missouri Learning Standards

Activities in *Nature Unhooked* are correlated to the Missouri Learning Standards (MLS, adopted 2017–2018) as well as the Next Generation Science Standards* (NGSS) to assist teachers and school administrators in aligning curricula to meet state standards. To allow a greater understanding of each standard, the three dimensions supporting each NGSS are included: science and engineering practices (SEP), disciplinary core ideas (DCI), and crosscutting concepts (CC). The integration of the three dimensions provides teachers with a context for the science content, an understanding of how the knowledge is to be attained and understood, and a set of concepts that have a universal meaning across disciplines.

Missouri Learning Standards	**Next Generation Science Standards**	**Science and Engineering Practices**	**Disciplinary Core Ideas**	**Crosscutting Concepts**	**Nature Unhooked Activity**
MLS	**NGSS**	**SEP**	**DCI**	**CC**	**Activity**
Chapter 1: The Structure and Properties of Water					
6-8.PS1.A.1 Develop models to describe the atomic composition of simple molecules and extended structures.	**MS-PS1-1** Develop models to describe the atomic composition of simple molecules and extended structures.	Develop a model	Substances are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms.	Scale, Proportion and Quantity	1.1, 1.4
6-8.PS1.A.2 Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.	**MS-PS1-2** Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.	Analyze and interpret data	*Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it. *Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants.	Patterns	1.3
Chapter 2: The Incredible Journey					
6-8.PS1.A.4 Develop a model that describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.	**MS-PS1-4** Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.	Develop a model	The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter.	Cause and Effect	2.1
6-8.ESS2.A.2 Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales.	**MS-ESS2-2** Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales.	Construct an explanation	Water's movements — both on the land and underground — cause weathering and erosion, which change the land's surface features and create underground formations.	Scale, Proportion, and Quantity	2.3, 2.4, 2.6, 2.7

Missouri Learning Standards	Next Generation Science Standards	Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts	Nature Unhooked Activity
MLS	**NGSS**	**SEP**	**DCI**	**CC**	**Activity**
6-8.ESS2.C.1 Design and develop a model to describe the cycling of water through Earth's systems driven by energy from the sun and the force of gravity.	**MS-ESS2-4** Develop a model to describe the cycling of water through Earth's systems driven by energy from the sun and the force of gravity.	Develop a model	Water continually cycles among land, ocean, and atmosphere via transpiration, evaporation, condensation and crystallization, and precipitation, as well as downhill flows on land. Global movements of water and its changes in form are propelled by sunlight and gravity.	Energy and Matter	2.1, 2.2, 2.5
Chapter 3: Matter and Energy					
6-8.PS1.A.2 Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.	**MS-PS1-2** Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.	Analyze and interpret data	Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants.	Patterns	3.1
6-8.PS1.B.1 Develop and use a model to describe how the total number of atoms remains the same during a chemical reaction and thus mass is conserved.	**MS-PS1-5** Develop and use a model to describe how the total number of atoms does not change in a chemical reaction and thus mass is conserved.	Develop and use a model	The total number of each type of atom is conserved, and thus the mass does not change.	Energy and Matter	3.1, 3.5, 3.6
6-8.LS1.C Construct a scientific explanation based on evidence for the role of photosynthesis and cellular respiration in the cycling of matter and flow of energy into and out of organisms.	**MS-LS1-6** Construct a scientific explanation based on evidence for the role of photosynthesis in the cycling of matter and flow of energy into and out of organisms.	Construct a scientific explanation	Plants, algae (including phytoplankton), and many microorganisms use the energy from light to make sugars (food) from carbon dioxide from the atmosphere and water through the process of photosynthesis, which also releases oxygen. These sugars can be used immediately or stored for growth or later use.	Energy and Matter	3.2, 3.6
None	**MS-LS1-7** Develop a model to describe how food is rearranged through chemical reactions forming new molecules that support growth and/or release energy as this matter moves through an organism.	Develop a model	Within individual organisms, food moves through a series of chemical reactions in which it is broken down and rearranged to form new molecules, to support growth, or to release energy.	Energy and Matter	3.2

Missouri Learning Standards	Next Generation Science Standards	Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts	Nature Unhooked Activity
MLS	**NGSS**	**SEP**	**DCI**	**CC**	**Activity**
6-8.LS2.B.1 Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem.	**MS-LS2-3** Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem.	Develop a model	Food webs are models that demonstrate how matter and energy is transferred between producers, consumers, and decomposers as the three groups interact within an ecosystem. Transfers of matter into and out of the physical environment occur at every level. Decomposers recycle nutrients from dead plant or animal matter back to the soil in terrestrial environments or to the water in aquatic environments. The atoms that make up the organisms in an ecosystem are cycled repeatedly between the living and nonliving parts of the ecosystem.	Energy and Matter	3.3, 3.4
Chapter 4: Interactions					
6-8.LS1.B.1 Construct an explanation for how characteristic animal behaviors as well as specialized plant structures affect the probability of successful reproduction of animals and plants respectively.	**MS-LS1-4** Use argument based on empirical evidence and scientific reasoning to support an explanation for how characteristic animal behaviors and specialized plant structures affect the probability of successful reproduction of animals and plants respectively.	Engaging in Argument from Evidence	*Animals engage in characteristic behaviors that increase the odds of reproduction. *Plants reproduce in a variety of ways, sometimes depending on animal behavior and specialized features for reproduction.	Cause and Effect	4.2, 4.3, 4.5
6-8.LS1.B.2 Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms.	**MS-LS1-5** Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms.	Construct a Scientific Explanation	Genetic factors as well as local conditions affect the growth of the adult plant.	Cause and Effect	4.2

Missouri Learning Standards	Next Generation Science Standards	Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts	Nature Unhooked Activity
MLS	**NGSS**	**SEP**	**DCI**	**CC**	**Activity**
6-8.LS2.A.1 Analyze and interpret data to provide evidence for the effects of resource availability on individual organisms and populations of organisms in an ecosystem.	**MS-LS2-1** Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.	Analyze and Interpret Data	*Organisms, and populations of organisms, are dependent on their environmental interactions both with other living things and with nonliving factors. *In any ecosystem, organisms and populations with similar requirements for food, water, oxygen, or other resources may compete with each other for limited resources, access to which consequently constrains their growth and reproduction. *Growth of organisms and population increases are limited by access to resources.	Cause and Effect	4.5
6-8.LS2.A.2 Construct an explanation that predicts the patterns of interactions among and between the biotic and abiotic factors in a given ecosystem.	**MS-LS2-2** Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems.	Construct a Scientific Explanation	Similarly, predatory interactions may reduce the number of organisms or eliminate whole populations of organisms. Mutually beneficial interactions, in contrast, may become so interdependent that each organism requires the other for survival. Although the species involved in these competitive, predatory, and mutually beneficial interactions vary across ecosystems, the patterns of interactions of organisms with their environments, both living and nonliving, are shared.	Patterns	4.1, 4.4
Chapter 5: Biodiversity					
6-8.LS2.A.1 Analyze and interpret data to provide evidence for the effects of resource availability on individual organisms and populations of organisms in an ecosystem.	**MS-LS2-1** Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.	Analyze and Interpret Data	Growth of organisms and population increases are limited by access to resources.	Cause and Effect	5.1

Missouri Learning Standards	Next Generation Science Standards	Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts	Nature Unhooked Activity
MLS	**NGSS**	**SEP**	**DCI**	**CC**	**Activity**
6-8.LS2.C.1 Construct an argument supported by empirical evidence that explains how changes to physical or biological components of an ecosystem affect populations.	**MS-LS2-4** Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.	Construct an Argument	Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations.	Stability and Change	5.2
6-8.LS2.C.2 Evaluate benefits and limitations of differing design solutions for maintaining an ecosystem.	**MS-LS2-5** Evaluate competing design solutions for maintaining biodiversity and ecosystem services.	Engaging in Argument from Evidence	Biodiversity describes the variety of species found in Earth's terrestrial and oceanic ecosystems. The completeness or integrity of an ecosystem's biodiversity is often used as a measure of its health.	Stability and Change	5.2
Chapter 6: People and the Environment					
6-8.LS2.C.2 Evaluate benefits and limitations of differing design solutions for maintaining an ecosystem.	**MS-LS2-5** Evaluate competing design solutions for maintaining biodiversity and ecosystem services.	Engaging in Argument from Evidence	Changes in biodiversity can influence humans' resources, such as food, energy, and medicines, as well as ecosystem services that humans rely on — for example, water purification and recycling.	Stability and Change	6.1, 6.2
*NGSS Lead States. 2013. Next Generation Science Standards: For States, By States. Washington, DC: The National Academies Press.					

Student Science Notebooks

Notebooks are used by scientists to record study procedures, data, observations, calculations, sketches, diagrams, and interviews and to establish and refine study design based on both successes and failures. They are different from a journal, which may be simply a record of thoughts, observations, and reflections. They can also be more than a science log that only contains data. Science notebooks are also an extremely useful tool in the process of teaching and learning science for students and teachers alike. Activities in this teacher guide encourage students to:

1. Develop their own methods of collecting, recording, organizing, analyzing, and presenting data from investigations and long-term observations.
2. Compare, collaborate, discuss, and present their methods and findings with other students.
3. Evaluate their methods, assess whether their investigations were well designed, and discuss possible alternatives to their methods.
4. Maintain ongoing records of all their discussions, observations, methods, challenges, and outcomes so that they may review them throughout the unit.

In this way, the science notebooks provide opportunities for students to apply similar authentic practices employed by scientists. They promote good data collection and record-keeping habits and serve as a valuable reference. Students begin to recognize science notebooks as useful resources for future methods, regardless of whether the methods were successful or not in the past. For teachers, science notebooks provide ample opportunity for formative assessment of student work and data organization, and mastery of content and skills, and serve as a means to guide the students' learning process.

For use with the *Nature Unhooked* unit, science notebooks are provided for each student. Students will be required to use their science notebooks for most activities for field study, project design, data collection and organization, recording of group discussion and collaboration, and activities connected to the Project Based Learning approach. Some pages provide templates needed for specific activities from the teacher guide.

The Value of Science Notebooks

Science notebooking is incorporated into all of the Discover Nature Schools curriculum units because of the value to academic disciplines, learning strategies, and instrumental assessment. The benefits are numerous:

- Authentic learning practices connecting learning to the real world.
- Application to different learning styles and differentiated instruction.
- Strengthening of science content and process skills including predicting, recording, organizing, analyzing, and interpreting data.
- Connections between academic disciplines of Science, Math, English Language Arts, Social Studies, and the Arts.
- Use in Project Based Learning (PBL), where inquiry of an authentic challenging problem or question is developed into student-driven action resulting in a public product, solution, or accurate explanation.
- Supports Science and Engineering Practices (SEPs):
  - Asking questions and defining problems.
  - Planning and carrying out investigations.
  - Analyzing and interpreting data.
  - Constructing explanations and designing solutions.
  - Engaging in argument from evidence.
  - Obtaining, evaluating, and communicating information.
- Allows teachers to assess students' understanding, to provide the feedback students need for improving their performance, and to determine:
  - prior knowledge and existing science ideas.
  - how conceptual understanding is being built.
  - procedural understanding.
  - mastery of curriculum goals.
  - the ability to apply and transfer ideas to new context.

Elements of Science Notebooks

While science notebooks may appear in different forms, including specific elements may result in a more beneficial product for students and teachers. The notebook should have a cover page that includes a title, student name, teacher's name, and school and class/section, if appropriate. The pages of the notebook should be numbered. Each page of the science notebook should have a title and headings. Heading information may vary, but the following information puts students in the habit of scientific documentation and is included for each activity heading entry.

- Date (Month/Day/Year)
- Time of Day
- Location
- Outdoor Air Temperature
- Description of Weather

Many of the student science notebook pages, provided with this unit, are already set up as a template with these standard headings. Repetition of this process reinforces good record-keeping and data collection techniques; these may be useful to students throughout their school experiences as well as their lives.

Science notebooks can also include a table of contents. This can be set up as a column of page numbers on the inside front cover of the notebook. Teachers can guide the students in composing headings for each page's content. This can be a great tool for students and teachers to quickly, and literally, be "on the same page." Developing a glossary of important terms at the back of the science notebook can be another reference tool.

Practical Application of Science Notebooks

- Notebook sessions can be started by presenting an anticipatory activity and posing a question based on the purpose of the lesson. The question should be used by the students as a way to focus on what they will be investigating.
- Have the students make predictions of anticipated outcomes.
- The students should make a record of tools and materials needed and used to conduct the activity, as well as planning and procedures that are implemented in order to gather the data.
- After an activity, ask students to organize their information. Instead of providing explicit instruction, allow students to use methods they think would work best (T chart, Venn diagram, lists, mind maps, various graphs, etc.). Afterward, have students share how they organized their information and allow them to self-assess how they could make improvements.
- Reflections and conclusions should be written by the students after completing the investigation. This is an opportunity to make connections between what they have observed and their prior experiences. Ask the students to explain what they have learned and then challenge them to write down any new questions that arise from what they have learned.
- Written entries should not be erased. Rather, if an entry needs to be amended with additional or corrected information, terms, or details, then these can be added as side notations or else referred to a different page, if needed, as an addendum. This serves as a record to the student's path of learning.
- Additional materials, pages, articles, photos, QR codes to particular web resources, and two-dimensional specimens can be glued, taped, stapled, or put into pockets added to the science notebooks.
- The science notebook should be readable, although neatness is not necessarily a priority. This is a dynamic science tool, not a final report.
- Use the "Line of Learning" reflective process. After the activity and classroom discussion in which students and student groups share the outcome of the lesson, have them draw a line in their notebooks. The teacher can reinforce content and clear up any misconceptions. This is a good location to add vocabulary. The students then return to the notebook to record new learning or revised thinking under the "learning line."
- Have students conduct self-evaluation of their science notebook entries. A scoring guide is included for this purpose and is printed in the student science notebook for easy reference. See Page 16.
- Collect and use the science notebooks for formative assessment. This is a good opportunity to check for content mastery and identify misconceptions that should be addressed. This assessment might also initiate shifting of teaching strategies to capitalize on avenues of student interest that might not have been anticipated. Use sticky notes to guide students to further develop areas where needed.

- Use science notebooks to collaborate with other teachers toward sharing and refining best practices in effective instruction.
- Teachers should keep a science notebook as well, writing, sketching, and making notations as time allows, demonstrating the behavior they wish to see in their students.

Scoring Guide for Science Notebook Entries

Score	Description	Criteria
4 points	Exceeds expectations	Data organized in a creative and/or meaningful way that supports a summary statement for the activity and includes questions for further investigation.
3 points	Meets expectations	Standard headings complete. Activity data complete and legibly written.
2 points	Partially meets expectations	Standard headings incomplete. Activity observations and data only partially completed.
1 point	Needs additional support	Many factors missing from standard entries and observations and data from the activity.
NS	Not scorable	Unreadable; no information recorded.

Resources

- Britsch, Susan and Daniel P. Shepardson. "The Art of Reviewing Science Journals." Science and Children, Nov.–Dec. 2004. Pages 43–45.
- Calhoun, Jeri and Ellen Mintz. "Project Notebook." Science and Children, Nov.–Dec. 2004. Pages 30–34.
- Full Option Science System Science Notebooks in Middle School The Regents of the University of California 28 pages — Accessed online on 04/04/2018 **fossweb.com/delegate/ssi-wdf-ucm-webContent?dDocName=D1423685**.
- Fulton, Lori; Campbell, Brian. Student-Centered Notebooks Science and Children, v42 n3 pages 26–29. Nov–Dec 2004.
- Fulton, Lori; Campbell, Brian. Science Notebooks Second Edition, Writing about Inquiry. Pearson Education. 2014.
- Joan Gilbert and Marleen Kotelman Five Good Reasons to Use Science Notebooks Science and Children Nov/Dec 2005. Pages 28–32.
- Moriarty, Robin, Jeff Winokur and Karen Worth. "Capitalizing on Literacy Connections." Science and Children, Feb. 2004. Pages 35–39.

Field Investigations in Your Schoolyard

Use of science notebooks and field investigation techniques by students are integrated components of the *Nature Unhooked* unit. The following information provides teachers with background knowledge on the importance of field investigations and how they relate to student learning.

Field investigations help students become systems thinkers, learn the skills of scientific inquiry, and understand that science doesn't only happen in a laboratory or classroom. Outdoor experiences in natural settings increase students' problem solving-abilities and motivation to learn in social studies, science, language arts, and math.

When planning and conducting field investigations, students and scientists grapple with the difficulties of working in a natural system and at the same time develop an understanding of its complexities and subsystems. Systems-thinking involves thinking about relationships, rather than about individual objects. A system can be defined in a number of ways:

- An assemblage of interrelated parts or conditions through which matter, energy, and information flow.
- An organized group of related objects or components that form a whole.

- A collection of things and processes (and often people) that interact to perform some function. The scientific idea of a system implies detailed attention to inputs and outputs and interactions among the system components.

State and national science education standards encourage instruction that focuses on problem-solving and inquiry — activities that characterize the pursuits of scientists. In field investigations, students pose a research question, then plan and conduct an investigation to answer that question. Students use evidence to support explanations and build models, as well as to pose new questions about the environment. Students learn that the scientific method is not a simple linear process and, most importantly, experience the difficulty of answering essential questions such as:

- What defines my environment?
- What are all the parts and interrelationships in this ecosystem?
- What is a healthy environment?
- What is humans' relationship to the environment?
- How has human behavior influenced our environment?
- How can our community sustain our environment?
- What is my role in the preservation and use of environmental resources?

Field investigations help students become informed citizen scientists who add knowledge to the community's understanding of an area in order to make issues of concern visible and share differing points of view about the preservation and use of community natural resources.

Classroom science often overemphasizes experimental investigation in which students actively manipulate variables and control conditions. In studying the natural world, it is difficult to actively manipulate variables and maintain "control" and "experimental" groups, so field investigation scientists look for descriptive, comparative, or correlative trends in naturally occurring events. Many field investigations begin with counts (gathering baseline data). Later, measurements are intentionally taken in different locations (for example: urban and rural, or where some natural phenomenon has created different plot conditions), because scientists suspect they will find a difference. In contrast, in precisely controlled experiments, scientists begin with a hypothesis about links between variables in a system. Variables of interest are identified, and a "fair test" is designed in which variables are actively manipulated, controlled, and measured in an effort to gather evidence to support or refute a causal relationship.

For conceptual clarity, we have identified three types of field investigations — descriptive, comparative, and correlative.

Descriptive field investigations involve describing and/or quantifying parts of a natural system.	**Comparative** field investigations involve collecting data on different populations/ organisms or under different conditions (For example: times of year, locations) to make a comparison.	**Correlative** field investigations involve measuring or observing two variables and searching for a relationship.

Each type of field investigation is guided by different types of investigative questions. Descriptive studies can lead to comparative studies, which can lead to correlative studies. These three types of studies are often used in combination to study the natural world.

Many of the activities in the *Nature Unhooked Teacher Guide* prepare students for field investigations. Students can utilize one or more of these types of investigations in connection to this unit.

A descriptive investigation might be one in which students observe, describe, measure, and quantify phenomena found at a field location such as a stream, lake, or pond. If similar data is collected from two different field locations, this could be framed as a comparative investigation. If students are able to identify a relationship between variables, then this would be a correlative field investigation. Science notebooks are an essential tool to be utilized in the field investigation process as well as in culminating field experiences. Information about conducting successful field experiences can be found in the *Field Experience* appendix.

Recording Outdoor Temperature with Students

Consider the following when purchasing thermometers for student use

- Provide one thermometer for every two or three students.
- If only a few thermometers are available, rotate temperature-reading responsibilities among students. However, all students should record temperature readings taken prior to each activity.
- Choose thermometers that are protected with some sort of plastic outer shell to prevent shattering or cracking when dropped.
- Choose thermometers that are calibrated in Celsius alone or in conjunction with Fahrenheit. The Missouri Department of Elementary and Secondary Education requires students to use Celsius when recording temperature.
- Choose thermometers with calibrations that are large and clear enough for students to read.
- Provide a box or container in which to store thermometers safely.
- Wipe thermometers carefully with a soft, damp cloth when necessary before storing.

Procedure for gathering outdoor temperature

1. Instruct students to hold thermometers carefully at the top (where the highest numbers are located) or by the plastic shield.
2. Students should not shake or swing thermometers but should hold thermometers steady.
3. Have students take an initial thermometer reading to serve as a baseline.
4. While holding the thermometer up and away from their bodies, students should check every few minutes for changes in the thermometer reading.
5. When students notice that no change in the reading has occurred after several checks, they should record the final reading in their science notebook heading.
6. To determine temperatures of various locations around the schoolyard or field experience area, students should take the initial, baseline thermometer reading and then carefully place the thermometer in the specific location to be measured (under a bench; under a rock ledge; on top of a rock; on the grass in the shade of a tree; etc.).
7. Students should check every few minutes for changes in the thermometer reading.
8. When students notice that no change in the reading has occurred after several checks, they should record the reading in their science notebook next to the description of the location(s) to be measured.
9. Students should carefully wipe dirt, leaves, etc. from thermometers with a soft, damp cloth.
10. Thermometers should be returned carefully to the designated storage box or container.

Resources

- Ryken, A. E., Otto, P., Pritchard, K., and Owens, K. 2007. Field Investigations: Using Outdoor Environments to Foster Student Learning of Scientific Processes. Pacific Educational Institute.
- Reprinted with permission from Dr. Margaret Tudor, Co-Executive Director of the Pacific Educational Institute, Market Place Office Building, 724 Columbia St. NW, Suite 250, Olympia, WA 98501 (mtudor@wfpa.org).

Discover Nature — Fishing

The Fisheries Division of the Missouri Department of Conservation provides an outdoor skills guide to teach citizens how to fish: *Discover Nature — Fishing Instructor Guide*. This educator guide can be used as a supplement to *Nature Unhooked* to introduce the outdoor skill of fishing. The use of *Discover Nature — Fishing Instructor Guide* with this curricular unit is optional. Some teachers may find it beneficial if culminating field experiences involve a fishing rotation. For further information and to order the resource, visit the Teacher Portal at **mdc.mo.gov/teachers**.

Unhooked in Action
PROJECT BASED LEARNING

Background

A valuable part of *Nature Unhooked* is its Project Based Learning (PBL) component, *Unhooked in Action*. PBL is an instructional method used to empower students to harness their knowledge and skills to solve real-world problems. It promotes 21st Century Skills such as critical thinking, collaboration, and creativity. PBL engages habits of mind such as thinking flexibly, questioning and posing problems, and applying past knowledge to new situations. By engaging students and schools with their community, students learn to communicate effectively with adults and organizations. They are also exposed to adult work environments and careers in the natural resources and conservation. "In PBL classrooms, students demonstrate improved attitudes toward learning. They exhibit more engagement, are more self-reliant, and have better attendance than in more traditional settings" (Buck Institute for Education, 2013).

For more information on Project Based Learning, the following resources are available

- Buck Institute of Education **bie.org**.
- ASCD article in Education Leadership: Seven Essentials for Project Based Learning **www.ascd.org/publications/educational_leadership/sept10/vol68/num01/Seven_Essentials_for_Project-Based_Learning.aspx**
- Book: Setting the Standard for Project Based Learning: A Proven Approach to Rigorous Classroom Instruction, John Larmer, John Mergendoller, Suzie Boss, ISBN-13:978-1-4166-2033-4.

The purpose of *Unhooked in Action* is to deepen the students' learning experience through hands-on practical learning that aligns with the standards, goals, and objectives outlined in *Nature Unhooked*. Projects can be simple or complex, and teachers have the option of guiding students to preferred projects. Examples of projects may include but are not limited to joining or creating a stream team, stenciling drains, installing a rain garden on the school grounds, or proposing a solution to a community problem at a city council meeting. Projects create a meaningful and impactful learning experience that makes a difference in the students' school or community. PBL is an approach to teaching and learning that connects curriculum to the real world. In this project students engage in civic and environmental literacy, understand implications of human actions, and work collaboratively to solve problems that have a direct impact on their lives. Types of PBL projects may include solving a real problem, exploring an abstract idea, conducting an investigation, or simply taking a position on an issue.

The project is broken into four phases. Phase one engages students by introducing them to the water issues in their community and school. Groups of students identify issues and solutions that they will evaluate in order to determine a possible project for the class to complete. In phase two the same student groups develop persuasive arguments based on evaluation criteria and present them to the class. Using the persuasive argument presentations, the class will choose the project(s) that will be completed. In phase three students develop a project scope and implement the project(s). The final phase of the project requires students to share their accomplishments and reflect on their learning. Detailed planning guides allow teachers and students to navigate the project more easily. Planning guides are included in the appendix.

By design, *Unhooked in Action* is not directly tied to the lesson plans within *Nature Unhooked*. Teachers may wish to introduce the project to the students at the beginning of the unit to have them begin thinking of issues or projects to address. Teachers may conduct different portions of the project throughout *Nature Unhooked* or use *Unhooked in Action* as a culminating event after completing the six *Nature Unhooked* chapters. As there are many different ways to conduct a PBL project, the *Unhooked in Action* guide sheets may be adapted as desired to fit individual teachers' needs.

Given that PBL projects are strongly connected to English Language Arts (ELA) concepts and skills, science teachers are encouraged to work with ELA teachers to demonstrate the importance of effective written and spoken communication in the sciences. To help structure the learning process and assist in meeting state standards, correlations to the Missouri Learning Standards for science as well as ELA are included at the end of this section. This learning process is also correlated to the Next Generation Science Standards.

Teacher Preparation

- During phase one of the project, students will be asked to identify current water issues within their community or on their school grounds. Anticipating these issues will help you shape and plan for project possibilities that will be helpful in guiding students to a project that is feasible.
- Fill out the *Possible Solution Criteria Master Guide*. This guide will be used by the students to help them evaluate and select a project.

Phase 1 Researching Water Issues

Step 1 Researching Community Water Issues

- In this step students will research water issues within their community. Water issues can be things like erosion, water pollution, water shortages, storm water runoff, flooding, filtering of water, wastewater treatment, outdated infrastructure, drought, etc.
- Have each student conduct a web or newspaper search and fill out the *Current Event Guide*.
- As a class, discuss what the students have discovered about the water issues in their community. Using a large piece of chart paper, write down the issues the students discover during their research. Focus on how the water issues impact the community, the school, and the students. Retain the brainstormed list for future reference. Students should also save the completed *Current Event Guide*.

Step 2 Water Issues Within the School

- Students may investigate the water issues within their own school through activities outlined in Chapter 2 of the teacher guide:
  - *2.3 Water Evidence Hike*
  - *2.4 Schoolyard Topography and Mapping*
  - *2.5 Runoff in the Schoolyard*
- As a class, discuss any water issues that were discovered in the schoolyard during the Chapter 2 activities. Write these issues down on a large piece of chart paper and hang them next to the community water issues. Focus on how these water issues impact the school and the students, and if any of these issues extend into their community (for example, water runoff from a parking lot polluting a local stream). Retain the chart paper sheets for future reference.

Phase 2 Uncovering the Project

Step 1 Identify a Problem

- Break the students into small working groups. Have the working groups complete the *School and Community Venn Diagram* and the *What Do We Know* guide, referring to the charts from the community and school water issue discussions.
- Have each working group choose one issue that becomes the problem they would like to promote as a class project.

Step 2 Defining Solutions

- Have each group fill out a *Mapping Solutions Guide* for their selected issue. Students will list the issue, name the root cause of the issue, and brainstorm three possible solutions to their selected issue.
- Using their *Mapping Solutions Guide* as a reference, have each working group fill out a *Possible Solution Criteria Guide* for each one of their three possible solutions. After the students have finished this step, they should have three Possible Solution Guides. An additional Possible Solution Guide is included for any additional solutions.

Step 3 Evaluating Solutions

- Hand out a copy of the completed *Possible Solution Criteria Master Guide* (completed by the teacher ahead of time) to each group. Have students compare their *Possible Solution Criteria Guides* with the *Possible Solution Criteria Master Guide* to determine the feasibility of each possible solution. Have the students use a red pen to note areas on their guides where they have questions, find areas of concern, or lack sufficient information. Monitor each group and be available for questions.
- Hand out one *Solution Evaluation Guide* to each group. Instruct students to refer to the Student and Master Solution Criteria Guides. Have students answer the questions as they evaluate each possible solution using the *Solution Evaluation Guide*. At the end of this step, students will have identified their best solution based on a simple ranking scale.

Step 4 Uncovering the Project

- Have each group complete the *Persuasive Argument Guide* using their highest ranked solution from the *Solution Evaluation Guide*. Groups should prepare a three- to five-minute persuasive argument for the class based on the *Persuasive Argument Guide*.
- Have each group present their problem and solution as a possible classroom project. List each problem and solution on a piece of chart paper for future reference.
- As a class discuss the possible problems and solutions that were presented.
- Decide which problem and solution to adopt as a class project. This can be done by voting or ranking the listed problems on the chart paper. Explain to the students that the solution(s) can be refined, revised, or changed completely during the Design and Implement phase.

Phase 3 Design and Implement

Step 1 Design the Project

- Discuss and complete the *Project Scope Guide* with the class. Have the students record the information on their own copy of the *Project Scope Guide*. Place a master copy of the *Project Scope Guide* in the class where students can access it.

Step 2 Implement the Project

- Monitor student progress as they work through the steps outlined in the *Project Scope Guide*. Use the calendar in the *Project Scope Guide* so that both you and the students can track and monitor project progress — keeping students on task and on time.
- Students should document their progress as they work through the project by taking notes, collecting data, writing reflections, and taking photos. This documentation will be used in their final presentation.

Phase 4 Present and Reflect

An important aspect of Project Based Learning is to present the work and accomplishments of the project. The purpose of this phase is for students to gain skills and experience in organizing and presenting their work. Presentations can take many forms, such as small group presentations to community leaders or classroom presentations to others. PBL products may also be written, in a digital multimedia format, or as a physically constructed product. In whatever form, students should be able to present the following:

- What was the project?
- What was the main goal?
- What did they do to accomplish the project?
- What went as expected, and what was unexpected?
- What was learned from expected and unexpected results?
- What would you do differently next time?
- How did this project influence the way you view human impacts on the environment?

Unhooked in Action — Project Based Learning

Correlations to the Next Generation Science Standards and the Missouri Learning Standards for Science

Correlations to the Missouri Learning Standards for English Language Arts

Unhooked in Action, the Project Based Learning component of *Nature Unhooked*, is correlated to the Missouri Learning Standards (MLS) for science (adopted 2017–2018) as well as the Next Generation Science Standards* (NGSS) and to the MLS for English Language Arts (ELA) (adopted 2016) to assist teachers and school administrators in aligning this portion of *Nature Unhooked* to meet state standards and to be used in both science and ELA coursework. To allow a greater understanding of each standard, the three dimensions supporting each NGSS are included: science and engineering practices (SEP), disciplinary core ideas (DCI), and crosscutting concepts (CC). The integration of the three dimensions provides teachers with a context for the science content, an understanding of how the knowledge is to be attained and understood, and a set of concepts that have a universal meaning across disciplines.

Missouri Learning Standards	**Next Generation Science Standards**	**Science and Engineering Practices**	**Disciplinary Core Ideas**	**Crosscutting Concepts**
MLS — Science	**NGSS**	**SEP**	**DCI**	**CC**
6-8.ESS3.C.2 Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.	**MS-ESS3.3** Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.	Constructing explanations and designing solutions (MS-ESS3-3)	**ESS3.C** Human Impacts on Earth Systems Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of other species. But changes to Earth's environments can have different impacts (negative and positive) for different living things. (MS-ESS3-3)	Cause and effect (MS-ESS3-3)
6-8.ETS1.A Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions. **6-8-ETS1.B.1** Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem. **6-8-ETS1.B.2** Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.	**MS-ETS1.1** Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions. **MS-ETS1.2** Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem. **MS-ETS1.3** Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.	Asking Questions and Defining Problems (MS-ETS1-1) Analyzing and Interpreting Data (MS-ETS1-3) Engaging in Argument from Evidence (MS-ETS1-2)	**ETS1.A:** Defining and Delimiting Engineering Problems The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that are likely to limit possible solutions. (MS-ETS1-1) **ETS1.B:** Developing Possible Solutions There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. (MS-ETS1-2), (MS-ETS1-3)	Influence of Science, Engineering, and Technology on Society and the Natural World (MS-ETS1-1)

Missouri Learning Standards — ELA
Reading Informational Text
6.RI.1.D Explain the central/main idea(s) of a text and cite evidence of its development; summarize the text.
7.RI.1.D Explain the central/main idea(s) of a text and explain the relationship between central idea(s) and supporting evidence; summarize the text distinct from personal opinions.
8.RI.1.D Explain the central/main idea(s) of a text and analyze its development over the course of a text; provide an objective summary of the text.
Writing
6.W.1.A Conduct research to answer a question, drawing on several sources; integrate information using a standard citation system.
7.W.1.A Conduct research to answer a question, gather relevant sources; integrate information using a standard citation system.
8.W.1.A Conduct research to answer a question (including a self-generated question); gather relevant, credible sources, print and digital; integrate information using a standard citation system.
6.W.2.A.B Follow a writing process to produce a clear and coherent writing in which the development, organization, style, and voice are appropriate to the task, purpose, and audience; develop with narrative, expository, and argumentative techniques. B. Expository: Develop informative/explanatory writing to examine a topic with relevant facts, examples and details.
7.W.2.A.B Follow a writing process to produce a clear and coherent writing in which the development, organization, style, and voice are appropriate to the task, purpose, and audience; develop with narrative, expository, and argumentative techniques. B. Expository: Develop informative/explanatory writing to examine a topic with relevant facts, examples and details; establish relationships between ideas and supporting evidence.
8.W.2.A.B Follow a writing process to produce a clear and coherent writing in which the development, organization, style, and voice are appropriate to the task, purpose, and audience; develop with narrative, expository, and argumentative techniques. B. Expository: Develop informative/explanatory writing to examine a topic with relevant facts, examples and details; establish relationships between ideas and supporting evidence.
7.W.2.A.C Follow a writing process to produce clear and coherent writing in which the development, organization, style, and voice are appropriate to the task, purpose, and audience; develop writing with narrative, expository, and argumentative techniques. C. Argumentative: Develop argumentative writing by introducing and supporting a claim with clear reasons and relevant evidence, instead of the informational/explanatory writing.
Speaking and Listening
6.SL.2.C Plan and deliver appropriate presentations based on the task, audience, and purpose, including multimedia components in presentations to clarify claims, findings, and ideas.
7.SL.2.C Plan and deliver appropriate presentations based on the task, audience, and purpose, including multimedia components in presentations to clarify claims, findings, and emphasize significant points.
8.SL.2.C Plan and deliver appropriate presentations based on the task, audience, and purpose, including multimedia components in presentations to clarify information, strengthen claims and evidence, and add interest.
*NGSS Lead States. 2013. Next Generation Science Standards: For States, By States. Washington, DC: The National Academies Press.

DIVING IN: The Science Notebook

Estimated Time

(1) 50-minute class period

Objectives

Students will be able to:

1. Become familiar with the purpose and use of a science notebook.
2. Record detailed observations and scientific data during a schoolyard field investigation.
3. Practice methods of organizing data and observations in a science notebook.

Teacher Preparation

This activity serves as an introduction to going outdoors and using science notebooks, both important elements of *Nature Unhooked*. Before doing this activity with students, take a tour of the schoolyard ecosystem and designate a portion of the area as the study area. Work with students to develop an outdoor plan including boundaries and behavioral expectations to be used whenever students are conducting activities outdoors.

Discussion of data collection techniques, and practice using sampling tools like thermometers can be conducted in the classroom prior to going outdoors.

Students use science notebooks to organize their thoughts, to document and organize data collection, to record questions for further investigation, to write summaries, to reference information during discussions, to self-assess, and to reflect on their learning. Teachers use student science notebooks to assess student learning, to identify science misconceptions recorded by students, to measure student growth, and to revise lessons. (See the sections on student science notebooks and field investigations in the front of this teacher guide.)

Students will add required headings to each science notebook activity entry and determine how best to organize data collected (for example, graphs, tables, charts, etc.) and will use these graphic organizers to summarize their learning.

This activity also introduces the concepts of biotic and abiotic factors as well as techniques of collecting baseline data that could be developed into descriptive, comparative, or correlative studies. It will also serve to initiate thinking and discussion pertaining to the crucial role of water in our communities and local ecosystems.

Materials

- Student science notebooks
- Pencils
- Thermometers
- Field guides for birds, insects, other invertebrates, and common plants of the area.
- Magnifiers (one per group)
- *Diving In: Schoolyard Ecosystem Baseline Data Sheet* (included in student science notebook)

Procedure

1. To prepare their science notebooks, have students:
   - Place their name, grade, and class period on the cover.
2. Have the students review the "Scoring Guide for Science Notebook Entry" (included in the student science notebook). Explain that at the end of the activity, they will be using this scoring guide to assess their own work.
3. Explain that the purpose of the notebook is for them to organize their thoughts, to document and organize data collection, to record questions for further investigation, to write summaries, to reference information during discussions, to self-assess, and to reflect on their learning.
4. Introduce the terms *abiotic* and *biotic. Abiotic* refers to factors in the ecosystem that are not alive, never were alive, and never will be alive. Have the students brainstorm things that would fall in this category, e.g. air, water, minerals, energy, climate, etc. Have them compare with the term *biotic,* which refers to all of the living organisms in an ecosystem, including matter that might not be living but was once living. Have the students list examples: birds, trees, sticks, animal droppings, etc. Have the students record relevant notes from this discussion in their science notebooks.
5. Divide the students into pairs or small groups. Review the parameters of the designated study area and the plan for outdoor activities with students before leaving the classroom.

   Have students:
   - Collect their science notebooks, pencils, field guides, thermometers, and other science tools.
   - Gather in the designated area in the schoolyard ecosystem.
   - Explain that they will be investigating the study area(s) and observing and recording the biotic and abiotic factors that they find. Student pairs/small groups spread out but remain close enough to hear teacher instructions, if needed, within the designated study area(s).
   - Have students open their science notebooks to *Diving In: Schoolyard Baseline Data* and review the expectations for this science notebook entry. The students are to record the abiotic and biotic factors that they find. Students should also write down questions that come up during their investigations.
   - Have the students complete the standard headings:
     a. Date
     b. Time of Day
     c. Location
     d. Outdoor Air Temperature (using Celsius; Fahrenheit optional)
     e. Weather (conditions recorded outdoors such as cloud cover, wind speed and direction, humidity, etc.)
   - Have the students make and record their biotic and abiotic observations.
6. Allow ample time for students to work through this first science notebook entry before having them retrieve their materials and return to the classroom. Students may use additional science notebook pages if needed.

Wrap-up

- Have each group share examples of their recorded observations.
- Discuss objects or factors that might not fit easily into either the biotic or abiotic groupings.
- Have them compile a list of their questions on a white board or flip chart sheet.
- Challenge the students to think about whether they had observed any patterns, relationships, or interactions between the biotic and abiotic factors observed. Have them provide examples, such as sunny versus shady, or if a particular factor/organism was found only in a particular area.
- Remind the students that this is a first activity of a science unit that investigates water, its physical properties, and the role that water plays on the Earth's surface, within ecosystems, and also in human communities. Ask the students to give examples of how water was found in the schoolyard. (Puddles, dew, clouds, moisture, humidity, etc.)
- Ask the students if, and how, they had organized the data that they had collected in their science notebooks. Challenge them to think about how they might organize it differently if the investigation were conducted again.
- Let the students know that later in the unit they will be investigating the biodiversity of the schoolyard using a more structured and systematic method (*Activity 5.1 Biodiversity in the Schoolyard*).
- Have students use the Scoring Guide for Science Notebook Entry (included in student science notebook) to assess their first science notebook entry.

Extension

1. Provide the students with examples of graphic organizers such as Venn diagrams, T-charts, graphs, and mind maps. Have them organize the data that they had collected during the *Diving In* activity into a graphic organizer within their science notebooks.
    - Create a T-chart or other graphic organizer of their choice to summarize their observations.
    - Write a summary paragraph of their observations and data collected.
    - Cite specific biotic and abiotic factors recorded during their observations to support their summary.
2. Use natural biofacts and artifacts, objects collected from your backyard, such as acorns, pinecones, leaves, mussel shells, pinned insects, snake skin, turtle shell, turkey feathers, rocks/fossils, or items on loan from a local conservation office such as mammal skulls or small pieces of mammal fur. Have students choose one object, observe it carefully, and record detailed observations of the object in their science notebooks. Encourage students to use their five senses as they study and describe their object.

    Have students:
    - Sketch their object and label parts, if possible.
    - Write a sentence that infers the best habitat for the object.
    - Write a question about the object.

Diving In: Schoolyard Ecosystem Baseline Data

Date _____ Outdoor Air Temperature _____

Time of Day _____ Weather _____

Location _____ _____

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Assessment

Scoring Guide for Science Notebook Entry

Score	Description	Criteria
4 points	Exceeds expectations	Data organized in a creative and/or meaningful way that supports a summary statement for the activity and includes questions for further investigation.
3 points	Meets expectations	Standard headings complete. Activity data complete and legibly written.
2 points	Partially meets expectations	Standard headings incomplete. Activity observations and data only partially completed.
1 point	Needs additional support	Many factors missing from standard entries and observations and data from the activity.
NS	Not scorable	Unreadable; no information recorded.

1 the STRUCTURE and PROPERTIES of Water

Estimated Time

(5) 50-minute class periods

Vocabulary

Adhesion
Atom
Cohesion
Density
Electron
Gas
Heat capacity
Hydrogen bond
Liquid
Molecule
Polar molecule
Proton
Solid
Solute
Solution
Solvent
Temperature

Activities

1.1 Modeling a Water Molecule
1.2 Cohesion and Adhesion
1.3 The Universal Solvent
1.4 Density of Water

Missouri Learning Standards

6-8.PS1.A.1 Develop models to describe the atomic composition of simple molecules and extended structures.
6-8.PS1.A.2 Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.

Next Generation Science Standards

Performance Expectations

(Science and Engineering Practices underlined)
MS-PS1-1 Develop models to describe the atomic composition of simple molecules and extended structures.
MS-PS1-2 Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.

Disciplinary Core Ideas

PS1.A: Structure and Properties of Matter

- Substances are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms. (MS-PS1-1)
- Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it. (MS-PS1-2)

Crosscutting Concepts

Scale, Proportion, and Quantity

- Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small. (MS-PS1-1)

Patterns

- Macroscopic patterns are related to the nature of microscopic and atomic-level structure. (MS-PS1-2)

Activity 1.1 Modeling a Water Molecule

Estimated Time

(1) 50-minute class period

Learning Standards

MLS: PS1.A.4
NGSS: PS1-1

Objectives

Students will be able to:

1. Create a model of a water molecule.
2. Identify the properties of a water molecule.
3. Demonstrate that water is a pure substance made of three atoms.

Teacher Preparation

In this activity, students will create a model of a water molecule. Before class, cut out and assemble the *Teacher's Water Molecule Model Template*. This template will be used to help guide the students during the lesson. Have students work in small groups. Each student will create six water molecule models, and each group will work together to create ice crystal maps using the water molecule models.

Materials

- Student science notebooks
- Pencils
- *Teacher's Water Molecule Model Template* (2 pages)
- *Student's Water Molecule Model Templates* (one per student)
- *Ice Crystal Map* (one per group)
- Colored pencils or crayons
- Scissors
- Double-sided sticky dots, double-sided tape, or glue

Procedure

1. Have students prepare headings in their science notebooks. (This is an indoor activity; therefore, temperature and weather factors may be left blank.)
2. Explain to the students that they are going to make a model of a water molecule. Holding up the *Teacher's Water Molecule Model Template*, explain that they are going to make six water molecules that look like the one you are holding, except smaller. Use this opportunity to talk about the properties of a water molecule.

   Q: What atoms make up a single molecule of water?
   A: Three atoms make up a single molecule of water. There are two atoms of hydrogen and one atom of oxygen in each molecule of water.

   Q: If you separate the atoms of a water molecule, is it still water?
   A: If you break the molecule apart, it stops being water and becomes individual atoms of hydrogen and oxygen — two substances with properties that are quite different from those of water.

Q: What are the properties of a hydrogen atom? (Hold up one of the hydrogen atoms from the *Teacher's Water Molecule Model Template* for the class to see.)
A: Hydrogen atoms only have 1 proton, 1 electron, and 0 neutrons.

Q: What are the properties of an oxygen atom? (Hold up the oxygen atom from the *Teacher's Water Molecule Model Template* for the class to see.)
A: Oxygen atoms have 8 protons, 8 electrons, and 8 neutrons.

Q: When two hydrogen molecules bond with an oxygen atom and make one water molecule, how many protons, electrons, and neutrons does it have?
A: Each molecule of water has 10 protons, 10 electrons, and 8 neutrons.

Q: Why does a single water molecule only have 8 neutrons?
A: The two hydrogen atoms of a water molecule do not have neutrons, and the only available neutrons come from the oxygen atoms.

Q: What is the shape of a water molecule?
A: Water atoms are arranged in such a way that they look like a teddybear's head.

Q: What are some other facts about a water molecule? (List the student answers on the board for them to reference later in the activity. Students may refer to pages 3–4 of the student book.)
A: Answers may vary but should include some of the following:

- The chemical formula for water is H_2O.
- Water is the universal solvent because many substances dissolve in water.
- Water is a pure substance because it has a definite and constant composition. Its composition does not vary.
- Many compounds contain hydrogen and oxygen, but water is the only one that has that special 2:1 ratio.
- Water is a polar molecule because its positive and negative charges are unevenly distributed.
- Polarity gives H_2O many of its distinct properties.

3. After the students have finished discussing the properties of water, hand out *Water Molecule Model Templates* and have the students:
   - Color the oxygen atoms red and the hydrogen atoms yellow.
   - Label (for each individual atom) the number of protons, electrons, and neutrons in the spaces provided for each.
   - Cut out each atom. To make six molecules of water, each student should have six oxygen atoms and twelve hydrogen atoms. While students color atoms, watch Water Polarity (time 3:51) **ed.ted.com/lessons/how-polarity-makes-water-behave-strangely-christina-kleinberg**
4. Using the *Teacher's Water Molecule Model Template,* demonstrate where to attach the hydrogen atoms to the oxygen atom. Explain that on the oxygen atom, there are eight dots, representing eight electrons, and on the hydrogen atom, there is one dot, representing one electron. Have students glue the hydrogen atoms to the top of the oxygen atom by placing one hydrogen atom on the top left dot of the oxygen electron and the other hydrogen atom on the top right dot of the oxygen electron.

Q: If each dot represents an electron, how many electrons can you count on this model? Is it correct?
A: There are only 8 visible electrons on this model because when the hydrogen atoms were glued to the oxygen atom, the dots representing the electrons on the oxygen atom were covered up. This model does not correctly demonstrate the total number of electrons represented in a water molecule.

Q: How can we fix our water molecule models to reflect the correct total number of electrons in a water molecule?

A: To reflect the correct total number of electrons in a water molecule, students should add a dot (electron) next to the dot on each of the hydrogen atoms. (Use the *Teacher's Water Molecule Model Template* to demonstrate where to place the dot/electron.)

Q: What do you notice about the number of hydrogen atoms and the number of oxygen atoms?

A: There is a 2:1 ratio of hydrogen to oxygen atoms.

5. On the back of the water molecule models, have students write their initials and one fact about a water molecule. Have them use the list created earlier in the lesson to complete this step. Students can use these water molecule models as flash cards to study water facts alone or in groups.
6. Break students into small groups and provide a copy of the *Ice Crystal Map*. Explain that this is a map of what water molecules look like when they are in a frozen state.
7. Have students:
   - Combine their water molecules with other group members to build an ice crystal similar to the ice crystal on the map.
   - Start with six molecules and build the structure out from those six molecules.

Wrap-up

Have students retrieve and save their original six water molecule models. These will serve as flash cards/study guides for future reference/assessments.

Extension

View the following videos:

- Water Polarity
  ed.ted.com/lessons/how-polarity-makes-water-behave-strangely-christina-kleinberg
- Why Does Ice Float?
  ed.ted.com/lessons/why-does-ice-float-in-water-george-zaidan-and-charles-morton

Cross-Curricular

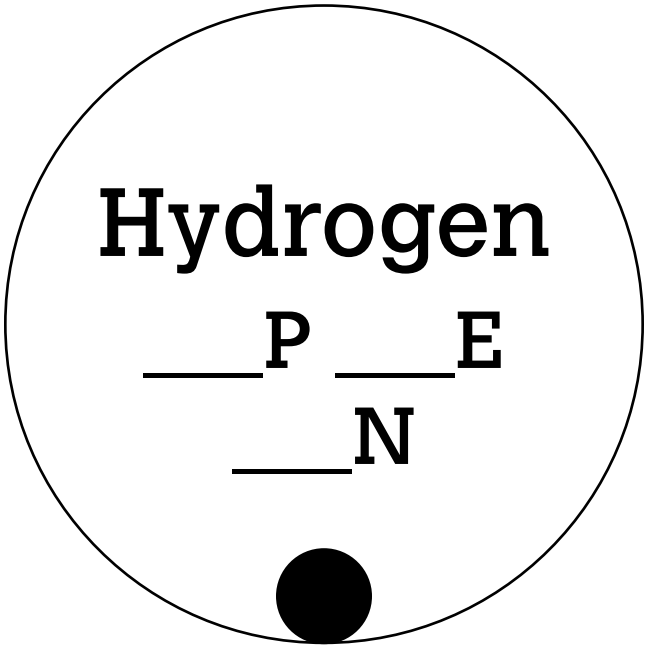
Using modeling clay, have students create a 3-D model of a water molecule, identifying the three atoms, and labeling parts.

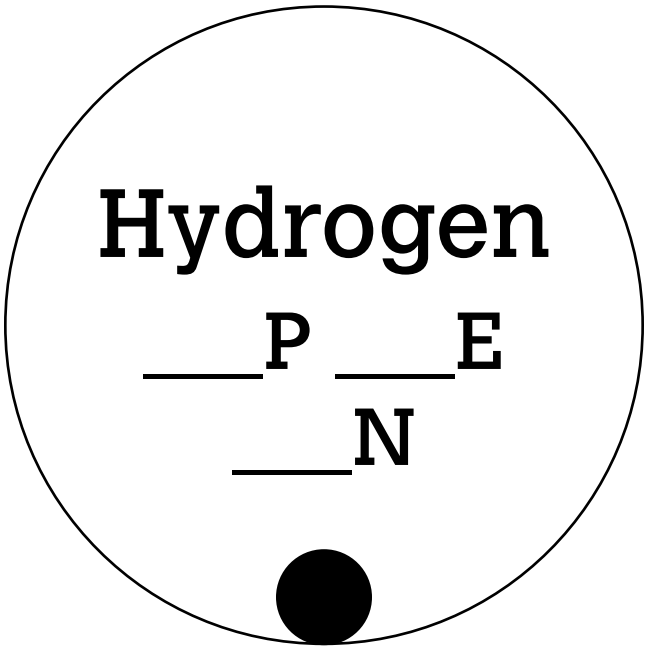
Fine Arts Connection — Divide students into small groups. Have each group produce a play acting out the formation of a water molecule. "Actors" will represent hydrogen and oxygen atoms. Have students create a script depicting the formation of a molecule and, if time allows, a script showing the separation. Students should be able to answer the question "If a water molecule is broken apart and separated, is it still water?"

Teacher's Water Molecule Model Template

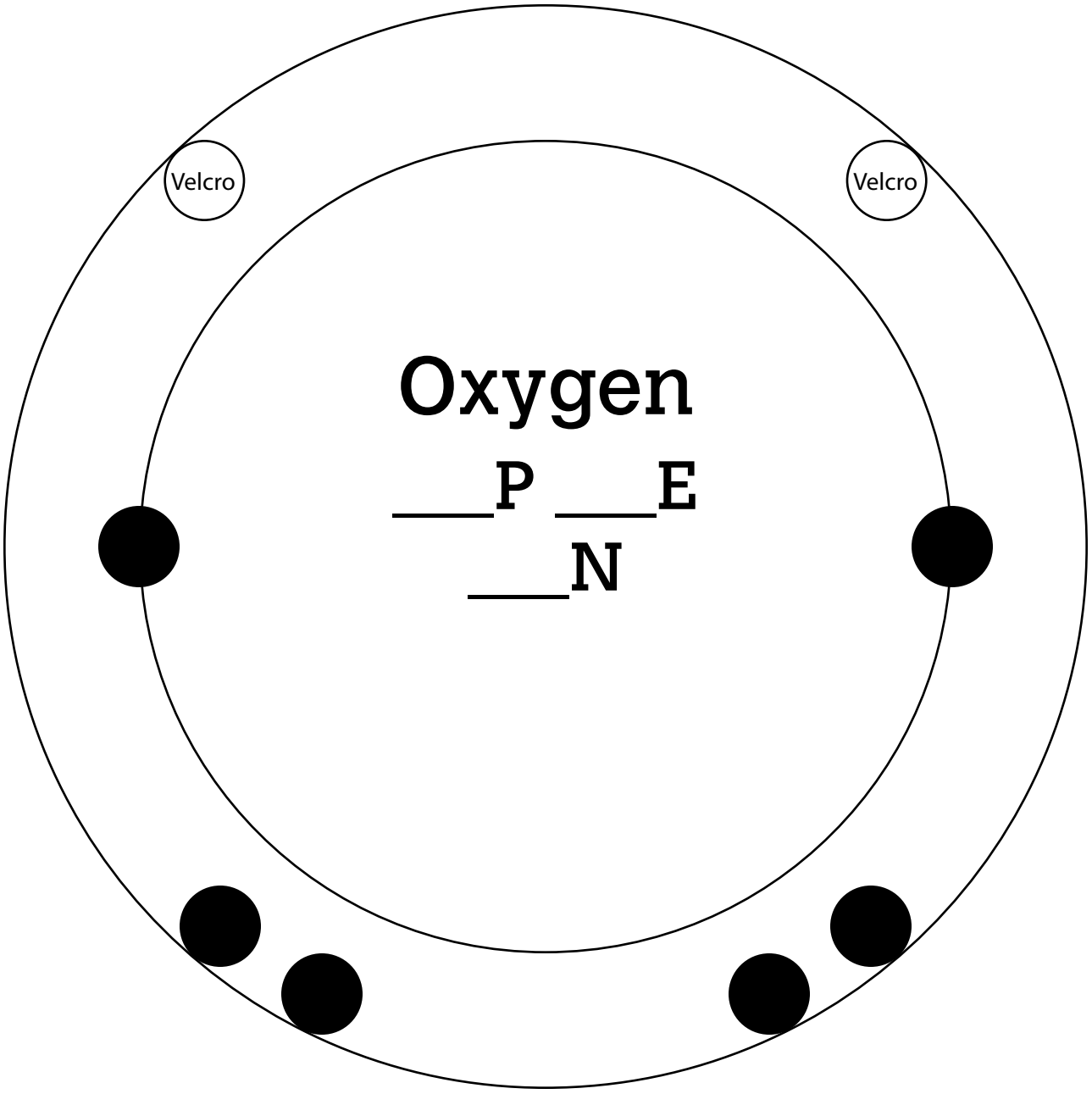
Directions:

- Cut out and laminate each atom, 2 hydrogen atoms and 1 oxygen atom.
- Place Velcro behind the electron dot on both of the hydrogen atoms.
- Place Velcro on the electron dots marked "Velcro" on the oxygen atom.

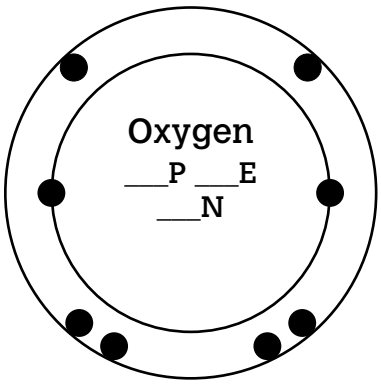


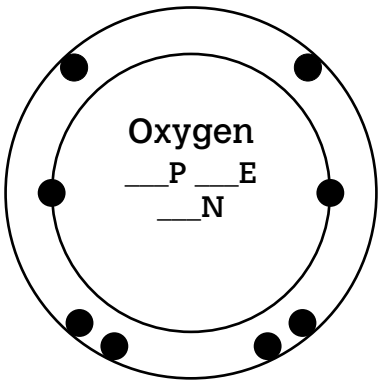


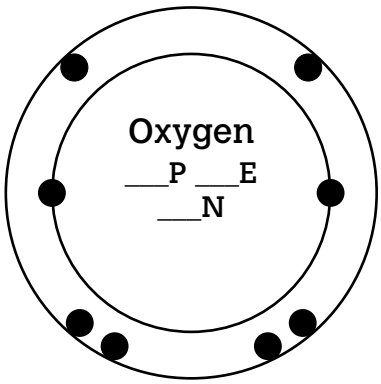
Teacher's Water Molecule Model Template

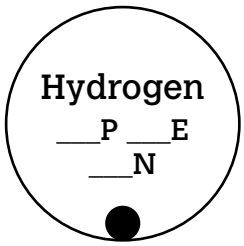


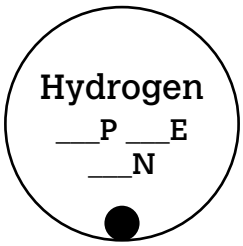
Student's Water Molecule Model Templates

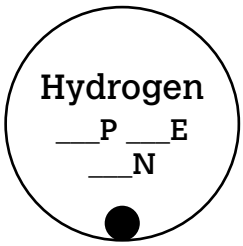


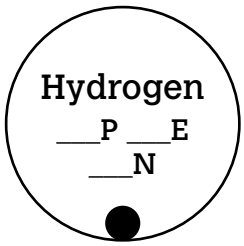


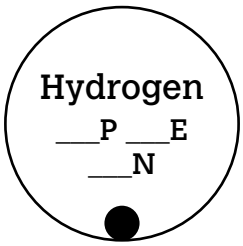


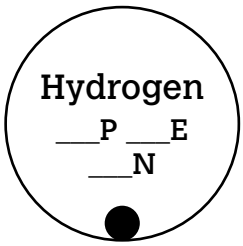


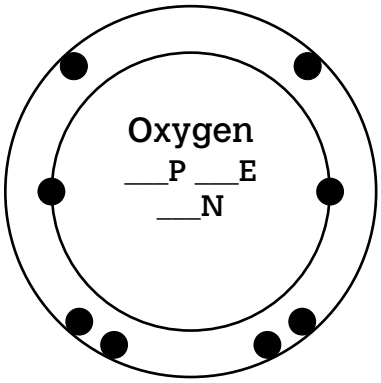


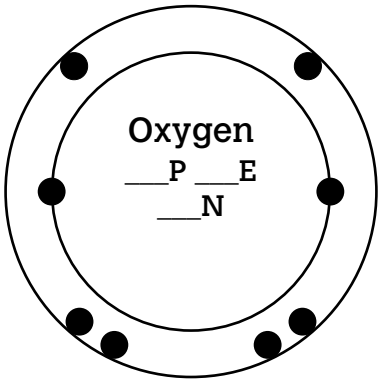


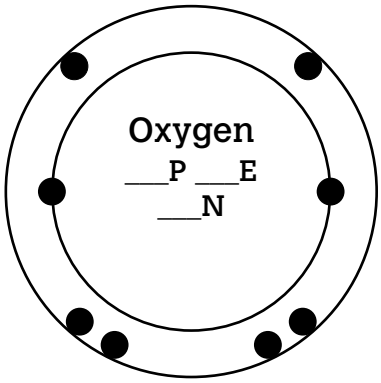


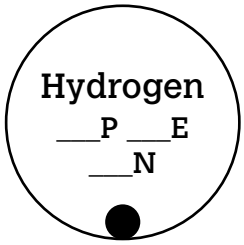


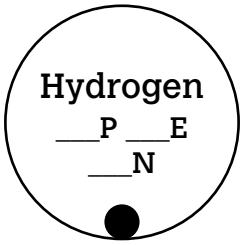


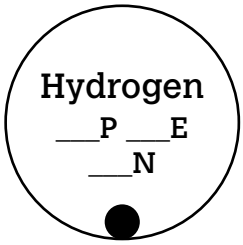


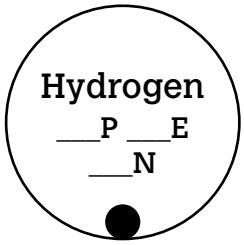


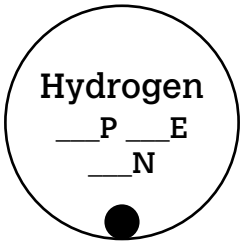


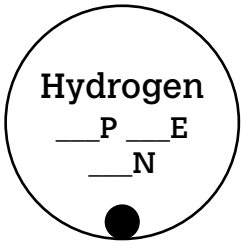




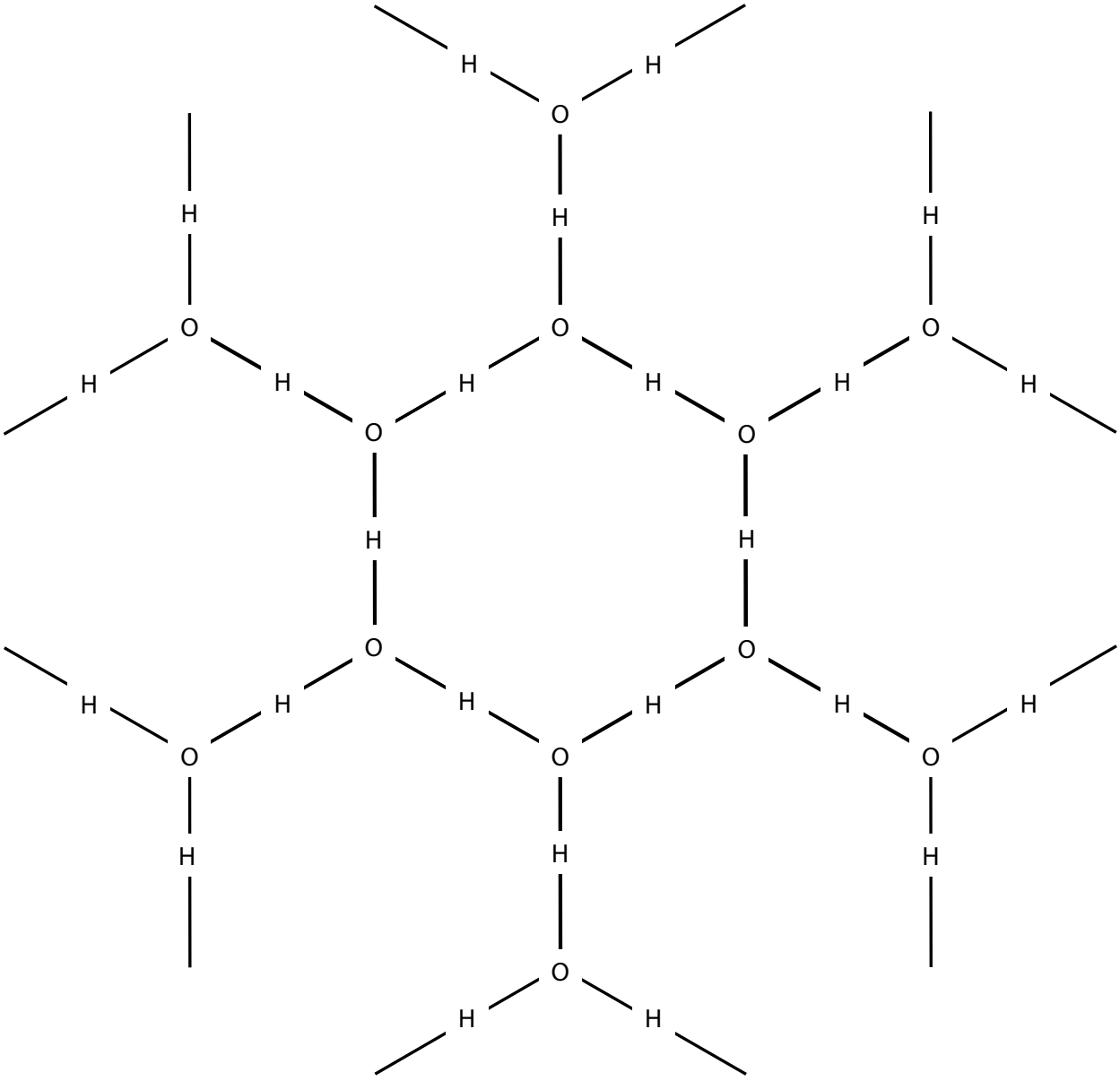








Ice Crystal Map



Activity 1.2 Cohesion and Adhesion

Estimated Time

(1) 50-minute class period

Learning Standards

MLS: PS1.A.2
NGSS: PS1-2

Objectives

Students will be able to:

1. Observe and describe two distinct properties of water (cohesion and adhesion).
2. Gather, analyze, and interpret data.
3. Explain how cohesion and adhesion may work together.
4. Explain how cohesion and adhesion are important for plants, animals, and people.

Teacher Preparation

This activity can be done in the classroom or science lab, if available. However, it can also take place outdoors in the schoolyard ecosystem using plastic containers and cups rather than glass. If outdoors, a flip chart or small white board and markers will be necessary. The first part of this activity will require a stable, flat surface and one penny per group. The second part of this activity will require a stable, flat surface and up to a roll of pennies per group. Both parts will require easy access to water.

Materials

- Student science notebooks
- Pencils
- *Activity 1.2 Number of Drops on a Penny* (included in student science notebook)
- *Activity 1.2 Number of Pennies* (included in student science notebook)
- Large containers to hold water
- 5–6 small glasses (or clear plastic cups if outdoors), all the same size
- 30–50 pennies per group (depending on the size of the glasses or cups)
- Dish soap (enough for 10 drops per group)
- 10–12 eyedroppers (two per group: one for pure water use and one for use with soap and water)
- Air thermometer (if outdoors)
- Flip chart or white board and markers (if outdoors)

Procedure

1. Have students complete their science notebook headings. Include air temperature and weather data if outdoors.
2. Divide students into 5–6 groups, assign numbers to each group, and provide each group a glass or cup, an eyedropper, and one penny.
3. Have students:
    - Open their science notebooks to *Activity 1.2 Number of Drops on a Penny*.
    - Predict how many drops of water can be dropped on the penny before the water runs off the penny.
    - Record their personal predictions.

4. Have groups:
   - Place one penny on a flat, stable surface.
   - Fill the eyedropper with water and begin slowly squeezing one drop at a time directly on the top of the penny.
   - Count each drop and record on the table in their science notebooks the total number of drops added to their penny before water began running off the penny.

5. Have groups discuss and record responses in their science notebooks:
   - How close were their predictions to the actual number?
   - How might they show their Actual Number of Drops compared to their Predicted Number of Drops? (Different graphic organizers)

Q: What did you notice about the surface of the water on your pennies?
A: A dome formed. Refer students to the photo on Page 4 of the student book.

Q: What property of water made the actual number of drops possible?
A: Cohesion, the attraction of one water molecule to another water molecule (positively charged hydrogen ends of a water molecule attracted to negatively charged oxygen ends of nearby water molecules) allowed water to form a dome over the penny. Cohesion produces surface tension.

6. Have groups:
   - Open their science notebooks to *Activity 1.2 Number of Pennies* table.
   - Place their glass or plastic cup on a stable, flat surface.
   - Get water from the large containers and fill their group's glass or cup with as much water as possible (at least to the rim).

7. Have groups:
   - Take turns gently slipping pennies, one at a time, into the glass or cup.
   - Count the number of pennies added until surface tension at the top of the glass or cup breaks and water runs down the side of the container.
   - Record in the "Pure Water" column of their table the number of pennies added before the surface tension broke.

Q: What happened to the surface of the water in your container as you added pennies?
A: The surface bulged up over the top.

Q: What properties of water are demonstrated by this bulge?
A: Cohesion, the attraction of one molecule to another of the same kind. Adhesion, the attraction between two different kinds of molecules.

Q: What causes the water to form a bulge?
A: Water molecules have an uneven distribution of charges, which explains why water molecules stick together (cohesion). Water molecules are also attracted to the sides of the container (adhesion), which anchors the sides of the bulge to the rim of the container.

8. Instruct groups to:
   - Dump half the water in their glass or cup back into the large containers of water.
   - Observe and sketch the shape of the surface of the water remaining in their glass or cup.

Q: What do you observe about the surface of the water remaining in your glass or cup?
A: There is a slight downward curve in the middle of the surface.

Q: What caused this curve? Why?
A: Adhesion is responsible for the slight curve you see. The water is attracted to the sides of the glass or cup because of the attraction between the two different kinds of molecules (water molecules and glass or plastic molecules.)

Q: Based on this observation, how should you always read the volume measurement in a graduated cylinder?
A: Because of adhesion, you should always read the volume measurement at the bottom of the curve.

9. Ask students to consider how the experiment might work using soapy water. Instruct them to individually predict whether they will be able to add more pennies, the same number of pennies, or fewer pennies after adding soap.
10. On the flip chart or white board, create the following chart titled "Predictions," and record students' general predictions for the 3 categories.

Predictions

More Pennies	Same Number of Pennies	Fewer Pennies

11. Have each group add 5 drops of soap to their half-filled glasses or cups. From the larger container of water, SLOWLY add water to the glasses or cups to the same level it was the first time. The water should be added slowly to avoid creating any bubbles. **Note:** larger glasses or cups may require more drops of soap.
12. Have groups:
    - Take turns gently slipping pennies, one at a time, into the glass or cup.
    - Count the number of pennies added until surface tension at the top of the glass or cup breaks and water runs down the side of the container.
13. Have students record in the "Water and Soap" column the actual number of pennies added before the surface tension broke and water ran down the side of the container.
14. On the flip chart/white board, create the following chart titled "Predictions."
15. After all students have finished recording their data, survey the class about their predictions. Record the number of students who made predictions for the three categories of the table.
16. On the flip chart/white board, create a table similar to *Activity 1.2 Number of Pennies* students used in their science notebooks with the addition of a column labeled "Group No."

Number of Pennies

Group No.	Pure Water	Water and Soap
	Actual No.	Predicted No. Actual No.
	Actual No.	Predicted No. Actual No.
	Actual No.	Predicted No. Actual No.

17. Have a member of each group record their data on the "Number of Pennies" chart on the flip chart/white board.
18. Discuss the data charts with the class and guide students to analyze and interpret the data. Compare the results of each group's penny activities.

Q: What do you notice about the results for each group?
A: Answers may vary depending on the results. Some numbers may possibly be the same for both pure and soapy water. Some may have added more or fewer pennies to the soapy water.

Q: Why do you think the results among groups are different?
A: Amounts of water may not have been equal between the two trials; surface tension may have broken before students noticed; measurements were not accurate; etc.

Q: Looking at all the results, what trend or pattern do you see?
A: More groups were able to slip more pennies into pure water than into water mixed with soap before the container overflowed.

Q: Using this class data, what can you infer about the properties of pure water compared to pure water mixed with soap?
A: Pure water exhibits properties of cohesion and adhesion more than water mixed with soap. Soap or other substances mixed in water can change the distribution of positive and negative charges in water molecules. This change in the distribution of positive and negative charges in water molecules reduces the water molecules' polarity, changes the physical properties, and breaks surface tension.

Q: How does your "Prediction" chart match the "Number of Pennies" chart?
A: Answers may vary. Discuss reasons behind student predictions, misconceptions students may have had, and reasons for expected or surprising results.

Q: Does the number of drops of soap make a difference in terms of how many pennies could be added before water flows over the side? How could we find out?
A: Design and conduct an experiment involving glasses/cups with different amounts of soap added. Discuss what evidence could be used to defend their answers.

Wrap-up

Allow time for groups to discuss:

- Examples of cohesion and adhesion in nature
- Ways cohesion and adhesion work together
- How cohesion and adhesion are important for plants, animals, and people

Assessment

Have students respond to the following in their science notebooks:

- Define cohesion and adhesion.
- Explain why pure water exhibits these properties.
- Give an example in nature of how cohesion and adhesion may work together.

Extension

Some items sink in water because they are denser than water. However, some of these same items may be able to be placed on top of the water's surface, allowing the surface tension to prevent the items from sinking.

1. Ask groups of students to consider items that are small and that normally sink, but that might rest on top or water due to surface tension. Have them make a prediction about one or more objects. (Suggestions might include paper clips, straight pins, and rubber bands.) Have students design and test an experiment and record their results and conclusions in their science notebooks.
2. Assuming that students are successful in "floating" an object, have students predict how they might cause a successfully floating object to sink without touching that object in any way. Groups should design and test an experiment and record their results and conclusions in their science notebooks.
3. Have groups discuss why their results did or did not support their predictions. For groups with results that did not support their predictions, students can redesign their experiment and test it.
4. Repeat the Number of Drops on a Penny activity using water mixed with soap. Have groups of students make predictions, and gather, analyze, and interpret data as described in the activity.

Cross-Curricular

Trees have internal plumbing that relies upon the properties of cohesion and adhesion. Have students create an illustration showing how cohesion and adhesion work together in a tree's internal plumbing, from roots to branches. (Students could label adhesion as the water drawing up and cohesion where molecules attach.)

Activity 1.2 Number of Drops on a Penny

	Predicted Number of Drops	**Actual Number of Drops**
1.		
2.		
3.		

1. How close were your predictions to the actual number?

2. How might you show the actual number of drops compared to the predicted number of drops?

Activity 1.2 Number of Pennies

Pure Water	**Water and Soap**	
Actual Number of Pennies	**Predicted Number of Pennies**	**Actual Number of Pennies**
Sketch of water surface before water spills over the edge.		
Sketch of water surface when container is partially filled.		

1. Define *cohesion* and *adhesion*.

2. Explain why pure water exhibits these properties.

3. Give an example in nature of how cohesion and adhesion may work together.

Activity 1.3 The Universal Solvent

Estimated Time

(1) 50-minute class period with a brief check-back after a couple of days

Learning Standards

MLS: 6-8.PS1.A.2
NGSS: MS-PS1-2

Objectives

Students will be able to:

1. Observe and distinguish between physical changes and chemical changes.
2. Explain what distinguishes a physical change from a chemical change.
3. Observe that solubility of solids in water generally increases with increasing temperature.
4. Observe that the solubility of gases generally decreases with increasing temperature.

Teacher Preparation

This activity may be done as a teacher demonstration or as a lab activity with students working in small groups. If done as a lab, the materials list should be multiplied by the number of student groups. This activity helps to lay the conceptual groundwork for water quality testing and water purification activities in Chapter 6.

Materials

- Student science notebooks
- Pencils
- Sheet of 8.5 × 11 inch paper
- Scissors
- Matches or lighter
- Glass or metal tray for safely containing burning paper
- 1 clear glass 250 mL beaker
- 3 cups of sugar
- Teaspoon
- Magnetic stirrer and stirring hotplate or hotplate and manual stirring rod
- 2 clear bottles of seltzer or other clear soda — one warm, one cold
- Pencil with a few inches of string tied around the middle

Procedure

1. Show the class an ordinary sheet of copy paper. Cut the paper into a few large pieces.

   Q: Have I made a physical change or a chemical change to the sheet of paper?
   A: Physical. It is still paper, just smaller pieces.

2. Cut one of the pieces into tiny pieces.

   Q: How about now? Have I made a physical change or a chemical change?
   A: Physical. It is still paper, just smaller pieces. Even if you could grind the paper up into a powder, it would still be paper. You would only have changed its physical appearance. With some effort you could still turn it back into a sheet of paper. Whether a sheet of paper, a smaller piece, a tiny piece, or even a powder, it is the same substance, which is really a plant material called cellulose.

3. Now take another piece of paper and light it on fire (carefully!).

Q: Have I made a physical change or a chemical change?
A: Chemical.

Q: How do you know?
A: What you are left with is not paper (not cellulose). It is not possible to turn it back into a piece of paper. The reaction (burning) gave off heat, light, and gas (smoke).

Q: What is the difference between a physical change and a chemical change?
A: A physical change may alter the state (solid, liquid, gas) or appearance (shape or form) of substances, but it does not change the fundamental identity of the substances. They are still made up of the same atoms arranged in the same way. In other words, they are still made of the same molecules. Physical changes can be reversed because all of the original substances are still there. A chemical change breaks the molecular bonds of the original substances and rearranges the atoms to form different molecules. Chemical changes cannot be reversed because the original substances no longer exist.

Q: How do the cellulose molecules in a piece of paper change when the paper burns?
A: They break apart and combine with oxygen from the air to form carbon dioxide, carbon (ash, soot, and smoke), and water. In the process, the breaking and reforming of molecular bonds releases energy in the form of light and heat.

4. Pour some water into a glass beaker.

Q: If I heat this water, will I be making a chemical change or a physical change?
A: Physical. Heating is not the same as burning. No chemical change takes place.

Q: How do you know?
A: You can let the water cool back down (or condense, if you boil it) and get all the water back.

5. Take a spoonful of sugar and hold it up to the class.

Q: What if I add this sugar to the water in the beaker? Will the change be physical or chemical?
A: Allow the class to offer varying hypotheses as to whether the change will be physical or chemical. Ask each respondent to explain why they believe the change is physical or chemical. Make notes on the board of their responses.

Q: If the change is physical, I should be able to get the original substances back, right?
A: Yes.

Q: How much sugar do you think will dissolve in this cup of water?
A: Allow responses, then say "Let's see."

6. Count as you add spoonfuls of sugar to the water, stirring as you go, until undissolved sugar begins to accumulate in the bottom of the beaker. Announce your result to the class.

Q: What if I heat the water? Will more sugar dissolve?
A: Yes.

7. Add the remainder of the sugar to the water, set it on the hotplate, and leave it heating.

8. Take the clear bottle of clear soda from the cooler and show it to the class.

Q: What will happen when I open this bottle of soda?
A: It will fizz.

9. Open the bottle, noting the hiss of gas escaping and the bubbles that form inside the bottle.

   Q: What caused the hissing sound? Where did these bubbles come from?
   A: Carbon dioxide gas is dissolved in the water of the soda under pressure. When you open the bottle, you relieve the pressure and allow gas to escape. Some of the gas comes out of solution.

10. Now take the bottle of the same soda from the window ledge where it has been warming in the sun.

   Q: What about this bottle of soda, which I left sitting on the window ledge in the sun? What will happen when I open it?
   A: It will explode/erupt with bubbles.

11. Open the bottle over the sink.

   Q: Why did so many more bubbles come out and with so much force?
   A: The gas is dissolved in the soda water under pressure, like before. But more gas comes out of solution when the soda is warm.

   Q: So you're saying that gas dissolves better in cold water than in hot water?
   A: Yes.

   Q: Would you say that dissolving a gas in water is a chemical change or a physical change?
   A: Physical.

   Q: Why do you think so?
   A: Because you can get all the original gas and water back.

12. Go back to the hotplate with the sugar dissolving in it.

   Q: It looks like more of our sugar has dissolved as the water has heated up. How do you explain that?
   A: Solids dissolve more easily in hot water than in cold water, unlike gases, which dissolve better in cold water than in hot water.

   Q: And is dissolving sugar in water a chemical change or a physical change?
   A: Physical, because you can get the original ingredients back.

   Q: How?
   A: Allow the water to evaporate and the dissolved sugar will recrystallize in the beaker.

13. Tell the class that you're going to test that hypothesis. Remove the beaker from the hotplate. Put the string into the sugar-water solution and place the pencil across the top of the beaker with the string hanging down into the sugar solution. Put the beaker in the window ledge in the sun. Tell the class that we'll leave the sugar-water solution here for a couple of days and see what happens.

Wrap-up

After a couple of days, you should be able to show the class that sugar crystals are forming on the string. Review the prediction that the original ingredients are recoverable because the dissolution of sugar in water is a physical change rather than a chemical change.

Activity 1.4 Density of Water

Estimated Time

(2) 50-minute class periods

Learning Standards

MLS: 6-8.PS1.A.2
NGSS: MS-PS1-2

Objectives

Students will be able to:

1. Analyze and interpret quantitative and qualitative data.
2. Create a model that demonstrates the properties of water in relation to temperature.
3. Explain how temperature affects water density.

Teacher Preparation

Students should work in small groups for this two-part (two separate days) activity. On Day 1 of the activity, students will determine the density of water and prepare an experiment to see if freezing water will change the density of water. On Day 2 of the activity, students will finish their experiment on temperature by calculating the density of their frozen water samples and create a model that demonstrates the effects of temperature on water density.

Note:

At the end of Day 1 activity:

- Students will need access to overnight freezer space for their graduated cylinders.
- You will need to freeze an ice cube tray filled with water dyed dark blue.

During Day 2 activity:

- You will need to place water in the clear, plastic, shoebox-size container at the beginning of the class in order to ensure it is at room temperature when you are ready to begin Step 5.
- You will need access to hot water.

Materials

- Student science notebooks
- Pencils
- *Activity 1.4 Density of Water Data Sheet* (included in student science notebook)
- Water (approximately 1–2 gallons)
- Plastic graduated cylinders (one per group)
- Scales (calibrated in grams)
- Water (at room temperature)
- Blue food coloring (10–20 drops)
- Red food coloring (10–20 drops)
- Freezer
- Clear plastic container (about the size of a shoebox)
- Small plastic bottle
- Hot water

Procedure

Day 1

1. Have students prepare headings in their science notebooks. Refer students to Page 6 of the student book for a review of density.
2. Review density with students.

   Q: What is density?
   A: Density is a measurement of how much matter is packed into a specific space.

   Q: How do you measure density?
   A: To measure density we need to know how much an object, or in this case, a liquid, weighs (mass) and how much space it occupies (volume). To find an object's density, you divide its mass by its volume (D = M/V).

3. Divide students into small groups. To calculate the density of water, each group will need a graduated cylinder, distilled water, and a scale that can measure in grams.
   A. To determine the mass of water, have students record the results of each step below in their science notebooks:
      - Weigh and record the mass of the graduated cylinder in grams.
      - Add distilled water to the graduated cylinder, leaving at least 3 inches of airspace at the top.
      - Weigh and record the mass of the filled graduated cylinder in grams.
      - Subtract the mass of the empty graduated cylinder from the mass of the filled graduated cylinder.
      - Label this in science notebooks as the mass of the water.

   B. To determine the volume of the water, have students:
      - Record in science notebooks the volume of water in the graduated cylinder.

   C. To calculate the density of the water, have students:
      - Use the formula Density = Mass/Volume.
      - Label this in science notebooks as the density of the water.

   Q: What causes solid water to be less dense than water in its liquid form?
   A: When water freezes, the crystal structure is formed by a more open organization of molecules.

4. Have students place their filled graduated cylinders in the designated freezer. Keep these in the freezer at least overnight.

   Q: Why should you be careful not to spill or add water to your cylinders?
   A: Losing or adding water will change the mass of the sample. The goal is to keep the mass the same but have a change in volume due to the water expanding.

5. Have students observe as you fill an ice cube tray with water and add enough drops of blue food coloring to make the cubes dark blue. Freeze this tray at least overnight. This will be used for the model segment of the activity on Day 2.

Day 2

1. Fill the clear plastic shoebox-size container with tap water at the beginning of the class.
2. Have students work in the same groups as Day 1 and retrieve their frozen graduated cylinder.
3. Have groups:
   A. Calculate the density of their frozen water samples and record the results of each step in their science notebooks:
      - Weigh and record the mass of their graduated cylinder (frozen overnight) in grams.
      - Subtract the mass of the empty graduated cylinder (recorded on Day 1) from the mass of the frozen graduated cylinder.
      - Label this in science notebooks as the mass of the frozen water.

4. Have groups:
    A. Determine the volume and density of the frozen water and record the results of each step in their science notebooks:
        - Record the volume of frozen water in the graduated cylinder.
        - Use the formula Density = Mass/Volume.
        - Label this in their science notebooks as the density of the water.
5. Have students analyze and interpret their data.

    Q: Based on your calculations, how does the density of your water in liquid state compare to the density of the same water in frozen state?
    A: The water in its frozen state is less dense than the water in its liquid state.

    Q: What factors might have affected results that would not support the idea that frozen water is less dense than liquid water?
    A: Answers may vary: Water was spilled or added to the graduated cylinder; the volume of water was misread; the formulas were miscalculated; etc.

    Q: Why did your results show that water is less dense in its frozen state?
    A: Water is weird. When the water froze, the hydrogen bonds joining the molecules lengthened. This pushed the molecules farther apart and made the solid water less dense than the liquid water.

    Q: How would you redesign this experiment to show that frozen water is less dense than liquid water?
    A: Answers may vary.

6. Have students finish analyzing, interpreting, and recording their data.
7. Have students predict whether hot water is less or more dense than cold water and record their predictions in their science notebooks.
8. Within clear view of the entire class:
    - Retrieve the tray with the dark blue ice cubes.
    - Place the clear plastic shoebox-size container (filled with water at the beginning of the class) on a table.
    - Have students take the room temperature and the temperature of the water in the container to ensure the water within the container is now at room temperature.
    - Fill the small plastic bottle with hot water and add enough drops of red food coloring to make the water dark red.
9. Explain to the class:
    - The water in this large container represents a body of water, like a lake.
    - The dark blue ice cube represents ice floating on the lake.
    - This bottle of (red) hot water represents the water in the lake heated by the sun.
10. Have students use their science notebooks to record their predictions to the following:
    - When a blue ice cube is added to the room-temperature water in the container, and the blue ice cube begins to melt, how will the cold blue-dyed water react? Will it rise to the top, float in the middle, or sink to the bottom?
    - When the hot, red-dyed water is added to the room-temperature water in the container, how will it react? Will the hot, red-dyed water rise to the top, float in the middle, or sink to the bottom?
    - When the hot, red-dyed water is added to the room-temperature water in the container, how will the blue ice cube react? Will it rise to the top, float in the middle, or sink to the bottom?
11. After students have made their predictions:
    - Place the blue ice cube into the water. Have the students record their observations.
    - Place the whole bottle of hot red water on its side (lid off) in the tank with the ice cube.
    - Have students record their observations of the red-dyed hot water and the blue ice cube.

12. Have students;
- Analyze and interpret the qualitative data they have collected by discussing the results of the experiment.
- Determine and discuss which of their results were quantitative and which were qualitative.

Wrap-up

After students have completed both activities, have them reflect in their science notebooks on the following (using short answer, drawing, diagram, etc.).
- How does temperature affect the density of water?
- How does the density of ice affect aquatic organisms?

Extension

Which has greater density? Students may come up with other ways to test their predictions, but one basic way would be to fill a sink or plastic tub with water and see which fruit, can, egg, etc. floats and which sinks.
- Have students work in groups to predict which of two items (one set) is more dense than the other in that set.
- Have groups determine ways to test out their predictions.
  - Examples of possible item sets:
    - Can of Coke versus a can of Diet Coke
    - Can of Coke versus a can of 7-Up
    - Can of 7-Up versus a can of Diet 7-Up
    - Compare different fruits:
      - An apple versus an orange
      - An orange versus a banana
  - A raw egg versus a hardboiled egg
- Have groups:
  - Discuss the results of their tests.
  - Discuss why/why not one item in each set was denser than the other.
  - Discuss other ways to test prediction.

Adapted from "The Answer Files" at **whyfiles.org/071questions/5.html**

Cross-Curricular

Oil and Water Droplet Paintings

This process painting activity demonstrates the density differences between oil and water. As oil is less dense, water sinks below oil, which is nonpolar.

Procedure: Using a small shallow pan (yet deep enough to hold a sheet of paper), place liquid watercolor (or water dyed with food coloring) in the bottom of the pan.

Pour 1/2 cup cooking oil into a small separate bowl. Have students use eyedroppers or pipettes to gather drops of oil to place in the shallow pan of colored water (or liquid watercolor). This will cause the less dense oil to remain on the surface, creating areas that will not transfer color to paper.

Place watercolor paper face down into the shallow pan and then place the paper on a drying rack. The finished result is a marbled effect of resist area created by the different densities of water and oil. Let the paintings dry, discuss water's polarity, and compare the densities of water and oil.

Activity 1.4 Density of Water Data Sheet

Day 1			**Notes**
Mass of Water Sample Filled Cylinder — Empty Cylinder = Mass of Water			
Mass of Filled Graduated Cylinder	**Mass of Empty Graduated Cylinder**	**Mass of Water**	
Volume of Water Sample Read the graduated cylinder to determine the volume of water			
Volume			
Density of Water Sample Density = Mass/Volume			
Mass	**Volume**	**Density**	

Day 2			**Notes**
Mass of Frozen Water Sample (**Note:** Use empty graduated cylinder measurement from Day 1)			
Mass of Filled Graduated Cylinder	**Mass of Empty Graduated Cylinder**	**Mass of Water**	
Volume of Frozen Water Sample Read the graduated cylinder to determine the volume of water			
Volume			
Density of Frozen Water Sample Density = Mass/Volume			
Mass	**Volume**	**Density**	

2 THE INCREDIBLE Journey

Estimated Time

(10) 50-minute class periods

Vocabulary

Aquifer
Condensation
Confluence
Crystallization
Dew
Erosion
Evaporation
Frost
Gravity
Infiltration
Nonpoint-source pollution
Point-source pollution
Precipitation
Runoff
Transpiration
Tributary
Turbidity
Water cycle
Watershed
Weathering

Activities

2.1 Search for Water Cycle Evidence
2.2 Transpiration in a Bag
2.3 Water Evidence Hike
2.4 Schoolyard Topography and Mapping
2.5 Runoff in the Schoolyard
2.6 Erosion in a Stream Table
2.7 Turbidity

Missouri Learning Standards

6-8.PS1.A.4 Develop a model that describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.
6-8.ESS2.A.2 Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales.
6-8.ESS2.C.1 Design and develop a model to describe the cycling of water through Earth's systems driven by energy from the sun and the force of gravity.

Next Generation Science Standards

Performance Expectations

(Science and Engineering Practices underlined)
MS-PS1-4 Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.
MS-ESS2-2 Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales.
MS-ESS2-4 Develop a model to describe the cycling of water through Earth's systems driven by energy from the sun and the force of gravity.

Disciplinary Core Ideas

PS1.A: Structure and Properties of Matter

- The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter. (MS-PS1-4)

ESS2.C: The Roles of Water in Earth's Surface Processes

- Water continually cycles among land, ocean, and atmosphere via transpiration, evaporation, condensation and crystallization, and precipitation, as well as downhill flows on land (MS-ESS2-4)
- Global movements of water and its changes in form are propelled by sunlight and gravity. (MS-ESS2-4)
- Water's movements — both on the land and underground — cause weathering and erosion, which change the land's surface features and create underground formations. (MS-ESS2-2)

Crosscutting Concepts

Cause and Effect

- Cause-and-effect relationships may be used to predict phenomena in natural or designed systems. (MS-PS1-4)

Scale, Proportion, and Quantity

- Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small. (MS-ESS2-2)

Energy and Matter

- Within a natural or designed system, the transfer of energy drives the motion and/or cycling of matter. (MS-ESS2.4)

Activity 2.1 Search for Water Cycle Evidence

Estimated Time

(2) 50-minute class periods

Learning Standards

MLS: 6-8.ESS.2.C.1, 6-8.PS1.A.4
NGSS: MS-ESS2-4, MS-PS1-4

Objectives

Students will be able to:

1. Describe ways water continually cycles among land, bodies of water, and the atmosphere.
2. Describe how water changes its state and location through the processes of evaporation, transpiration, condensation, crystallization, precipitation, infiltration, and surface runoff.
3. Create a model of the water cycle based on sketches/photos taken by them during a hike around the schoolyard ecosystem.

Teacher Preparation

This activity combines a review of the water cycle and a schoolyard ecosystem hike to record evidence of the water cycle. Students will make observations around the school to identify various stages of the water cycle. Students may capture evidence with pictures or sketches that will be used to create a model of the water cycle. This is a good activity for small groups and can easily be covered in two class sessions.

Materials

- Student science notebooks
- Pencils
- Air thermometers
- Cameras, or cell phones or tablets with cameras (optional)
- Scissors
- Glue
- Craft, natural, or recycled materials to create a collage

Procedure

1. Review the changes in states of water as it moves through the processes of evaporation, transpiration, condensation, crystallization, precipitation, infiltration, and surface runoff.

   Q: As water molecules move through the water cycle, what changes of state occur, and what are some samples of water changing location?

   A: Evaporation, transpiration, precipitation, runoff, infiltration, crystallization, condensation. Precipitation, runoff and infiltration are examples of water changing location.

Q: How would you describe/define/explain each of these?

A:
- Evaporation is a change of state from liquid to gas and is caused by sunlight warming the water and changing it into invisible water vapor.
- Transpiration is the process in which plants release water vapor through tiny holes in their leaves called stomata.
- Precipitation can be liquid (rain) or solid (hail or snow), and it is caused when water molecules condense on microscopic particles (such as dust specks), group together, and gain enough mass to be pulled down by gravity.
- Runoff is caused when precipitation hits the ground faster than it can soak in and flows downhill. Melting snow or ice can become runoff.
- Infiltration occurs when some precipitation falls onto land and soaks into the ground.
- Crystallization occurs when water becomes colder (loses heat energy) and its molecules slow down and become less tightly packed. It results in ice, snow, sleet, and hail.
- Condensation occurs as water vapor rises in the atmosphere, cools, and changes back into liquid, forming clouds or fog. This is a change of state from gas to liquid.

Q: Why does water move in this way?

A: Water moves from state to state due primarily to the energy of sunlight and from location to location due to the forces of Earth's gravity.

Q: Where are the molecules moving?

A: Answers may vary.

Q: What evidence of the water cycle might be found within the school or outdoors on the schoolyard ecosystem?

A: Answers may vary.

Q: What evidence is there that matter is conserved in these changes?

A: Answers may vary.

2. Explain to students that they will take a slow hike around the schoolyard ecosystem to gather evidence of the water cycle in action. They have the option to draw/sketch their evidence or to take photos/videos of it using optional available technology resources. They will use these photos/videos to create a collage/model/video of the water cycle as evidenced in the schoolyard ecosystem. Students should work in groups.
3. Have students complete science notebook headings and use thermometers to take the air temperature.
4. Take students on a slow hike around the schoolyard ecosystem. Allow students time to find and take or sketch pictures that show evidence of the water cycle and/or the water cycle in action. Students should capture images of things such as plants, clouds, drains, hills, puddles, water marks on structures, etc.
5. In the classroom, have students print and/or cut out sketches/photos and use the pictures to create a collage/model/video of the water cycle found in the schoolyard ecosystem.

   Have students:
   - Include labels of the action occurring in the water cycle.
   - Present their final products to the class.
   - Discuss similarities and differences of each product.
   - Display the models.
6. Using their final product to show their evidence, have each group state a claim about which water cycle processes have occurred in the schoolyard ecosystem.

Wrap-up

1. Have students describe and explain their model of the water cycle in their science notebooks.
2. Have students present their models of the schoolyard ecosystem water cycle to a group of lower grade students, to parents during a parent night, at a share fair, etc.

Resources

- McKinney, Barbara (1998). A Drop Around the World. Nevada City: Dawn Publications.

Extension

Have students write an essay about the "journey" of a water drop. Students can begin the water drop's journey where they choose and follow its travels through various parts of the water cycle.

Cross-Curricular

Investigative Reporting

Divide students into pairs. One student will be an investigative journalist or news reporter, the second student will be an "eyewitness." Have students write up and act out a script of an investigative journalist reporting a breaking news story of water cycle evidence in the community. The reporter can interview the eyewitness. For more varied results, the teacher may wish to give each pair a specific topic of "water cycle evidence" such as: Fog moving through community, runoff in local parking lots, crystallization of water, or any of the processes of evaporation, transpiration, condensation, crystallization, precipitation, infiltration, or surface runoff.

Activity 2.2 Transpiration in a Bag

Estimated Time

(2) 50-minute class periods

Learning Standards

MLS: 6-8.ESS2.C.1
NGSS: MS-ESS2-4

Objectives

Students will be able to:

1. Explain how water continually cycles through land, bodies of water, and the atmosphere.
2. Describe how water changes its state through the processes of evaporation, transpiration, and condensation.
3. Create an experiment to demonstrate how global movements of water and its changes in state are propelled by sunlight and gravity.

Teacher Preparation

This activity allows students to see and measure evidence of transpiration and evaporation. Visit a predetermined area in the schoolyard ecosystem prior to having students set up their investigations. Look for an area with different size leaves that are easily accessible to students. If you choose to continue the investigation for more than one day, the area should be somewhat protected. A sunny, warm day will encourage more transpiration. Students should work in groups and collect evidence from the investigation site(s) hourly, twice a day, or daily for a week.

Materials

- Student science notebooks
- Pencils
- *Activity 2.2 Transpiration in a Bag Student Data Sheet* (included in student science notebook)
- Classroom plant with leaves, a branch with leaves from the outdoors, or an artificial branch with leaves (to demonstrate the outdoor investigation)
- One demonstration bag attached to real or artificial leaves and with a small amount of water in it
- Small plastic bags (zip-up styles in quart or gallon sizes)
- Pens or permanent markers
- Air thermometers
- Plant field guide or identification chart
- Graduated cylinder
- Pipette

Procedure

1. Review the concepts of transpiration and condensation and how they differ.

   Q: What factors might have an impact on the amount of transpiration that occurs daily?
   A: Leaves versus needles on a plant; size and number of leaves and/or needles; amount of shade versus sunlight; temperature, etc.

   Q: How are transpiration and condensation different?
   A: Transpiration is when plants release water vapor through tiny holes in their leaves called stomata. Condensation is a change from gas to liquid. It occurs when water vapor cools and changes back into liquid.

   Q: What forms of condensation can we see?
   A: Clouds and fog in the air, dew and frost on ground-level surfaces, and glass of ice water on a hot humid day.

2. Demonstrate data collection procedures. Stress the importance of accuracy in collecting data.
   - Show students an example of a plastic bag with a group number or name and a site number or description written on it with permanent marker.
     - This is the first thing each group should do when they decide on their investigation sites.
     - Groups will label a new bag for each investigation site before taking the steps below.
   - Using the real or artificial branch with leaves, show students how to:
     - Choose several leaves from an easily accessible branch.
     - Open the plastic bag and (without breaking leaves off from the branch) carefully place several leaves inside the bag capturing the leaves in the bag with the opening at the top of the leaves/branch.
     - Zip the bag up tight enough to keep any liquid from getting in or leaking out but without harming the leaves or the branch.
   - Explain they will repeat these steps for each investigation site.
   - Have students turn to *Activity 2.2 Student Data Sheet* in their science notebooks.
   - Explain that before leaving each investigation site, they should:
     - Complete all information on the lines above the actual table on the student data sheet, including the location of each investigation site/bag.
     - Use a separate data sheet for each investigation site.

3. Inform students how often each investigation site will be checked. Student data sheets allow for up to five entries. Any number of entries can be used, and entries can take place several hours apart in one day or over a series of days. Gathering data over a series of days would allow for more weather variations and provide additional information for discussion, graphic organizers, etc.

4. Demonstrate data collection.
    - After the predetermined time has lapsed, explain that students will check on each of their investigation site bags. They will need their student data sheets, a graduated cylinder, and a pipette (optional).
    - Demonstrate while explaining the following. Students should:
        - Record the Date, Time, and Temperature on the student data sheet for that specific investigation site.
            - While one student records data on the student data sheet, another student should:
                - Carefully open the top of the bag and remove the leaves without losing any of the liquid in the bag.
                - Carefully pour the water from the bag into the graduated cylinder using the pipette to draw up any extra water droplets and add those to the cylinder.
                - When as much liquid as possible has been removed, return the same leaves in the same bag and zip up the closure.
                - Record the amount of water removed from the bag.
                - Repeat at any other investigation sites.
        - Explain that, when students return to the same sites at later times/days, they will record the Time Elapsed from Previous Collection. Under the "Collection 1" column, the time elapsed is from when the bag was originally placed on the branch.
5. Divide students into small groups. Provide each group with a permanent marker and a bag for each investigation site.
   Explain that all students should complete their science notebook headings and record relevant information about investigation sites in their science notebooks. Although students in each group are collecting data together, each student should enter the data in their own science notebook.
6. Take students outdoors and show them the predetermined area within the schoolyard ecosystem for this activity. Remind groups to keep their investigation sites within this area.
7. Have groups:
    - Choose a data collection/investigation site (a tree or other plant with easy access to its leaves/needles).
    - Inventory their sites to begin collecting information needed for the student data sheet (specific location of the site; specific weather factors; description of plant to be able to identify it back in the classroom; etc.).
    - Follow proper steps to prepare each investigation site by choosing and enclosing leaves/needles in the plastic bag.
    - Have groups check each bag for proper placement to avoid losing water from the bag.
8. Back in the classroom, have students work in their groups to:
    - Identify the plant species from science notebook information taken outdoors, if necessary.
    - Predict whether factors such as recent rain or drought conditions will affect the amount of water transpired.
    - Predict how long it would take for "X" amount of water to transpire.
    - Discuss what conditions might speed up or slow down the process.
    - Predict whether thermal or wind energy will have an effect on the amount of transpiration.
9. For each data collection session, remind students to:
    - Match the correct student data sheet with each investigation site.
10. Suggested data collection schedules:
    - Day 1 — 20 minutes to set up investigations in the schoolyard ecosystem; 10 minutes in the classroom to predict factors that affect transpiration.
    - Day 1 (hourly) — allow 10 minutes each hour collecting data at the investigation site(s).
    - Day 1 (2 collections or more) — allow 10 minutes for each collection of data.
    - Day 2–5 — 10 minutes each day for collection of data.
    - Last Day — Add a little more time to retrieve all investigation site materials.

11. When the last collection of data is complete, have students:
    - Complete the student data sheet.
    - Summarize the data collected.
    - Create a graph or table depicting the data.
    - Write at least one question they had while conducting their investigation.
12. For the class, have each group:
    - Describe their plant species and location of their investigation.
    - How accurate were their predictions?
    - Describe their data and their graphic organizer.
13. Have students discuss and compare all results. Prompts for discussion:
    - What specific characteristics support transpiration of plants?
    - Why did certain species or locations result in higher transpiration?
    - Why does the water collect at the bottom of the bag?
    - What forces are at work in this process?
    - What characteristics of water support transpiration from plants?
    - Where did water in the bag come from?
    - What factors affected the amount of water collected?
    - What were your questions during your investigations, and what are some of the answers to those investigation questions?
    - Where does the plant get its energy?
    - What is happening to the energy in this system?
14. In their science notebooks, have students:
    - Use vocabulary terms to explain where the water in the bag is coming from and the processes involved.
    - Draw a diagram to depict how water is moving through the water cycle within the bag (use terms to label diagram).
    - Sketch and describe what occurs outside the bag.
    - Use labels to identify the processes caused by sunlight and gravity.
    - Write a paragraph summarizing the characteristics and conditions using data from the observations that support transpiration from plants in the water cycle.

Cross-Curricular

Have students brainstorm in groups ways to utilize transpiration from plants into a specific service or product. Have students share presentations with class.

"Soaking It Up" Celery Experiment

The process of transpiration involves capillary action, moving water from a plant's roots to other parts of the plant. To explore how capillary action delivers water through a plant, place a freshly cut stalk of celery in a cup of water that has several drops of food coloring added.

Note: A smaller stalk with leaves still connected works best.

Activity 2.2 Transpiration in a Bag Student Data Sheet

Students _____

Investigation Site Location _____

Plant Species _____

Overall Weather Factors _____

	Collection 1	**Collection 2**	**Collection 3**	**Collection 4**	**Collection 5**
Date					
Time					
Temperature					
Amount of Water Collected					
Time Elapsed From Previous Collection					

1. Predict factors (such as recent rain or drought conditions) that will affect the amount of water transpired.

_____
_____
_____

2. Predict the length of time it would take for _____ amount of water to transpire.

_____
_____
_____

3. Use a graph, data table, or paragraph to summarize your data below or on an additional science notebook page.

Activity 2.3 Water Evidence Hike

Estimated Time

(1) 50-minute class period

Learning Standards

MLS: 6-8.ESS2.A.2
NGSS: MS-ESS2-2

Objectives

Students will be able to:

1. Make observations and identify evidence or clues to the presence of water in or near the schoolyard.
2. Record evidence of how the presence or movement of water has changed the Earth's surface in or near the schoolyard.
3. Classify evidence according to varying time and spatial scales.
4. Collect evidence that will be used to construct explanations in subsequent activities.

Teacher Preparation

This is an outdoor schoolyard exploration in which students think and act like detectives — making observations, identifying clues, recording details, classifying information, and collecting evidence that points to changing of the Earth's surface in their schoolyard due to the presence of water.

This exploration will set the stage for other activities in this chapter in which students will examine the effects of water on the landscape more closely. Guide students to notice areas where water has existed, has flowed, and may have caused weathering or erosion. Help students discover erosion problems in their schoolyard, potential problems, or opportunities for improvement to help them prepare for their Project Based Learning (PBL) project, *Unhooked in Action*.

Materials

- Student science notebooks
- Pencils
- *Activity 2.3 Water's Impact in the Schoolyard* (in student science notebook)
- Cameras, or cell phones or tablets with cameras (optional)
- Air thermometer

Procedure

1. Before going outdoors, have students predict and list evidence or clues to the presence of water they may find in their schoolyard. Ask students to consider water in the past, present, and future, and remind them that water can exist naturally in three states — solid, liquid, and gas. Have students consider both natural and human-made types of evidence, and all clues — both small and large.

   Q: What would you expect to see as evidence of water in the schoolyard?
   A: Wet grass from dew, frost, or precipitation; collected water, ice, or snow in puddles, ponds, creeks, or ditches; tracks in wet or dried mud; rivulets or channels where soil or rocks have been moved by flowing water; areas where soil or gravel moved by water has collected; stormwater drains in parking lots; gutters, downspouts, or splash guards; ice guards on roofs; ditches, canals, or culverts; exposed pipes or drains; etc.

2. Have students complete their science notebook headings and take and record outdoor air temperature.

3. Assemble students outdoors and have them walk slowly through the schoolyard, looking for evidence or clues to the presence of water. Instruct students to list all evidence or clues in their science notebooks. In addition to listing evidence, students may also take photos of their discovered evidence or clues.
4. If students have difficulty, ask questions that may encourage them to slow down or be more observant.

   Q: Can you find spots or streaks of dirt at the base of structures? What could cause this?
   A: Raindrops falling on bare soil can splash mud on nearby surfaces.

   Q: Can you find spots of dirt on windows or other surfaces? What could cause this?
   A: Airborne dust can collect on raindrops, which later evaporate.

   Q: Can you find certain plants that prefer or can tolerate a lot of water? Are they concentrated in a certain area? Why?
   A: Plants such as rushes, sedges, cattails, and willows are indicators that water is present or has been present in the past. They may be present where water collects in the schoolyard.

5. Encourage students to view the landscape outside the schoolyard, if possible, and have them add any evidence of water they can see to their list. For example, a string of sycamore trees in the distance may indicate a riparian corridor of a nearby stream.
6. When students have completed their lists, have them circle their examples of evidence in which water has changed the Earth's surface in their schoolyard (or nearby) due to weathering or erosion.
7. Instruct students to find *Activity 2.3 Water's Impact in the Schoolyard* charts in their science notebooks.
8. Have students classify their examples of evidence by listing them under the appropriate categories in *Activity 2.3* chart titled *"Size of Water's Impact."* Students should list only the examples of evidence in which water has changed the Earth's surface. Instruct students to list at least one example of evidence under each column.

For example, students may have discovered these items of evidence, or similar ones:

"Small" column

- Mud splashed on the school's foundation by falling raindrops
- Small cracks or rivulets discovered on a hill in the schoolyard that seemed to be formed by trickling water that carried away small bits of rock and soil

"Medium" column

- Larger cracks, rivulets, or channels in the soil made by erosion
- Gullies or ditches

"Large" column

- Ponds or lakes
- Stream or river channels
- River bluffs
- Dissected hills
- Valleys or floodplains
- Sinkholes

9. Have students consider how much time they think would be required for the development of each example of evidence they have listed. Instruct students to reclassify their examples of evidence by listing them under the appropriate categories in *Activity 2.3* chart titled *"Length of Time of Water's Impact."* Students should list only the examples of evidence in which water has changed the Earth's surface.

Wrap-up

Q: Is there a relationship between the size of water's impact and the length of time required for that impact? If there is a relationship, what is it?

A: Students may come to the conclusion that small impacts can happen quickly while medium and large impacts often take more time. Students may be familiar with the extensive time required to carve Johnson's Shut-Ins or the Grand Canyon.

Q: Does this relationship always exist?

A: Usually, although students will probably be able to think of sudden high-impact water-related events like flash floods, earthquakes that cause tsunamis, mudslides, and sinkholes that suddenly collapse.

Q: Is there an erosion problem or potential erosion problem in our schoolyard? How can we know for sure? What evidence could we collect? How can we find out the extent of the problem? Can we find a solution to the problem?

A: Open-ended questions for discussion. Discovered problems may be placed under consideration for being addressed in the PBL project, *Unhooked in Action*.

Extension

Students may organize their collected digital images of evidence or clues to the presence of water in a digital presentation program. Students may make presentations to the class.

Cross-Curricular

To further demonstrate water's ability to change the Earth's surface, give each student a piece of colored candy (like Skittles) on a paper plate and a water dropper or pipette of water. Have students add water droplets to the candy and record their findings. The teacher may wish to have students chart the number of drops as well as any results on a blank science notebook page. Discuss the following with students:

- What did the water represent in this activity?
- What did the candy represent?
- What did the coloring of the candy represent?
- What processes occur in nature and what are the results? (Answers may vary.)
- Explain how this activity served as a model.

Taking It Home

Have students interview family members to share a specific site or place where they have witnessed evidence of erosion, weathering, or stream channel changes. Have students brainstorm solutions to human-caused weathering/erosion problems and share their findings with the class. For more about erosion, view the YouTube video Make Your Own Erosion! SciShow Kids at **youtube.com/watch?v=YETdZyZI6es**.

Activity 2.3 Water's Impact in the Schoolyard

Size of Water's Impact		
Small	**Medium**	**Large**

Length of Time of Water's Impact		
Short	**Medium**	**Long**

Activity 2.4 Schoolyard Topography and Mapping

Estimated Time

(1) 50-minute class period

Learning Standards

MLS: 6-8.ESS2.A.2
NGSS: MS-ESS2-2

Objectives

Students will be able to:

1. Construct a map of their schoolyard.
2. Record evidence of the movement or presence of water in their schoolyard.
3. Identify high and low places in their schoolyard.
4. Identify the watershed in which their schoolyard fits.

Teacher Preparation

Watersheds are determined by the topography of the land. This includes the surface landforms and the geology of the underlying substrate. The surface landforms make up the surface drainage patterns. The quality and quantity of the water in rivers, lakes, and groundwater can be affected by human activities such as industry, development, farming, forestry, and mining. Streams and rivers are made up of drainage water and springs. The quality and quantity of the water in these streams and rivers are products of the land above them. This means that everything that happens on the land in a watershed affects the water moving through the watershed.

In this activity, students will use the information from the previous activity and continued observations outdoors to identify specific areas on a topographic map and in the schoolyard where water might flow and collect. This will help reinforce students' understanding of how water is drained by the changes in land elevation. Students may work in small groups as they identify areas on their maps, but each student should have a copy of the map. The goal is for students to make the connection between the "bird's-eye view" of a topographic map, an aerial map, and their schoolyard. Finally, they will discover where their schoolyard fits in a watershed.

Materials

- Student science notebooks
- Pencils
- Topographic map of your schoolyard — one copy per student (enlarged if needed)
- Aerial photo of your schoolyard — one copy per student (enlarged if needed)
- Markers or colored pencils
- Metric ruler
- Metric tape measure
- Clipboards
- Compass
- Light-colored string or rope at least 150 feet long
- Cameras, or cell phones or tablets with cameras (optional)

Procedure

Indoors

1. Obtain a topographic map of the area that includes your schoolyard at **topozone.com/missouri**. Other good sources for topographic maps are **cares.missouri.edu/portfolio/item/missouri-map-room** and **https://dnr.mo.gov/gis/simplemapviewer.pdf**.
2. Obtain an aerial photo of your schoolyard. Aerial photos may be printed from **nature.mdc.mo.gov/discover-nature/places**. You may also view more detailed information and a free aerial photo of your schoolyard at **earthexplorer.usgs.gov**.
3. Prepare a base map of the schoolyard for students to draw and record their observations. You may need to enlarge the map or photo 250 percent or more. You can include a few features that students can use as reference points such as parking lots or buildings.

Outdoors

4. Take a compass outdoors with the class to determine which direction is north. Have students orient their maps with the schoolyard and mark north on their maps. Leave a blank rectangle shape for a legend and plenty of space for the students to draw on the maps and add color and symbols to the legend. These maps may be used with future activities.
5. Review findings from *Activity 2.3 Water Evidence Hike* with the class. If necessary, take another trip around the schoolyard to observe and note features like stormwater drains, ditches, and other places where water might move or collect. Discuss any local geographic features in the schoolyard that were caused by water changing or eroding the surface of the Earth.

Indoors (or gathered outdoors)

6. Instruct students on how to read a topographic map. Look at contour lines and specific symbols on a map of the area. As a class, choose symbols that students will include in their legends, such as those for buildings, pavement, trees, grass, art wall, sidewalk, sports fields, etc. Give each student a copy of the base map you have prepared and the following questions to guide their observations:

   Q: Where did you (or might you) find water puddles?
   A: You will find water puddles in low areas, usually where water has run off and collected.

   Q: Which way does water flow?
   A: Water flows from higher areas to lower areas because of the force of gravity.

   Q: Does water go into any drains in the ground? Where do you think water goes after it leaves stormwater drains?
   A: Depending on where you live, water flows from stormwater drains into local streams and rivers or into sewage treatment plants. As stormwater flows along, it picks up pollutants from the land's surfaces and carries them to streams, rivers, and lakes.

Outdoors

7. Have students identify where the high points and low points are in their schoolyard, and make note of these points on their maps.
8. Have students stand at arm's length apart in the schoolyard and stretch out their arms or hold a single long string or rope parallel to the slope. Have a student stand at a distance and take a photo of the line of students.
9. Move the line of students to several areas and take photos from each location to test the students' predictions of the highest and lowest points in the schoolyard.
10. Allow students to view the photos and ask them if their predictions were correct. Why or why not?
11. On their maps, have students mark the highest point in the schoolyard with an X.
12. On their maps, have students mark the lowest point in the schoolyard with an O.

Indoors

13. Direct students to add features to their maps using markers or colored pencils. Have students draw in any water features present on the campus such as ponds, streams, wetlands, etc. Students should draw arrows indicating the direction and path that water may flow on or around the schoolyard. Arrows should point away from areas the water drains off of (high points) and toward areas that it drains to (low points).
14. To make a scale for the maps, pick something on the aerial photo that is easy to measure, like a sidewalk or a line on a basketball court. Have students use rulers to measure the length of the sidewalk or line on the aerial photo. Record the measurement, and then go outdoors and measure the actual sidewalk or line with a tape measure. Now, you have a scale. If the sidewalk in the photo is 5 cm and the actual sidewalk is 40 meters, the map scale will be 5 cm = 40 meters. Students should record the scale on their maps.
15. Students may need time to complete the features on their maps. Use class discussion to identify the similarities and differences in their findings.
16. Display the schoolyard maps.
17. Review the concept of watersheds and how they connect Earth's ecosystems. Explain to students that no matter where they are, they are always within a watershed.
18. If possible, project a map of the rivers of Missouri. A river map may be found at **geology.com/lakes-rivers-water/missouri.shtml**.
19. Determine the location of your school on the map and mark the location.

    Q: What is the closest tributary, creek, or river to your school?
    A: Answers may vary.

    Q: What is the closest major river to your school?
    A: Answers may vary.

20. If possible, project a map of the watersheds of Missouri. A watershed map may be found at **mdc.mo.gov/your-property/greener-communities/missouri-watershed-inventory-and-assessment**.
21. Determine the location of your school on the map and mark the location.

    Q: In which watershed is your school located?
    A: Answers may vary.

22. On the watershed website, click on the individual watershed in the left column to find more information about your watershed.

    Q: How many square miles does your watershed drain?
    A: Answers may vary.

    Q: Which smaller watersheds are contained within your larger one?
    A: Answers may vary.

Extension

1. To help students understand contour lines, start by drawing a small, irregularly-shaped oval (2 × 3 inches) using a half-piece of construction paper or cardstock. Move 1/4 inch out and draw around the first shape. Continue drawing the lines 1/4 inch out until you have 5 contour lines. Make 5 copies of this drawing. Cut out each shape so you have 5 shapes, ranging from the smallest to the largest. Arrange them in layers starting with the largest shape on the bottom. Add each one that is 1/4 inch smaller until you have 5 shapes in a pile. Lay a piece of copy paper on top and use a pencil or crayon to rub the surface until you see the shapes forming. You should be able to distinguish the contour lines in the rubbing.
2. To see how contour lines depict increasingly higher elevation, arrange the shapes on a pencil. Begin with the largest shape first by piercing it with a pencil. Continue to pierce the next largest shape, arranging all shapes in layers on the pencil with a half-inch of space between each shape. When all 5 shapes have been pierced and placed on the pencil, you have a visual representation of an increasingly elevated piece of land.

Cross-Curricular

Have students create 3-D models using foam core or corrugated cardboard, using the instructions from the first Extension activity, above. Use topography maps for reference.

Resources

- *Missouri Lakes, Rivers, and Water Resources* — Includes a map of the rivers of Missouri **geology.com/lakes-rivers-water/missouri.shtml**.
- *Missouri Watershed Inventory and Assessment* — Includes a map of the watersheds of Missouri and gives information about them **mdc.mo.gov/your-property/greener-communities/missouri-watershed-inventory-and-assessment**.
- *Watershed* — Includes information about Missouri Stream Team and how you can help protect our water **dnr.mo.gov/env/wpp/watersheds.htm**.
- *Surf Your Watershed* — Allows students to access specific information about the watershed in which they live, including information about cleanups, monitoring activities, restoration projects, and other activities. **cfpub.epa.gov/surf/locate/index.cfm**.

Activity 2.5 Runoff in the Schoolyard

Estimated Time

(2) 50-minute class periods

Learning Standards

MLS: 6-8.ESS2.C.1
NGSS: MS-ESS2-4

Objectives

Students will be able to:

1. Observe and compare the amount of surface water runoff in two different schoolyard sites.
2. Identify areas likely to experience greatest runoff during a rainstorm.
3. Investigate the processes of surface runoff, infiltration, and erosion by using a model to simulate rainfall on 3 different types of surfaces.
4. Describe the negative impacts of excessive surface water runoff on water quality.
5. Explain how plants reduce the amount of surface water runoff.

Teacher Preparation — Part 1 Outdoor Runoff Survey

During this activity, you will be taking students outdoors for a schoolyard runoff survey. Students will work individually to determine what factors affect the amount of runoff occurring in an area. Before class, investigate the school grounds and identify two runoff study sites. Each site needs to accommodate the whole class at one time. Select one site prone to excessive surface water runoff during a rainstorm — for example, a site with a slope, a hard-packed surface, or a paved parking lot. Select another site with little surface water runoff during a rainstorm — for example, a flat, well-vegetated area.

Materials

- Student science notebooks
- Pencils
- *Activity 2.5 Runoff Study Site Data Sheet* (included in student science notebook)
- Two 2-liter bottles (or similar measured containers for four liters) filled with water

Procedure

1. Briefly review the water cycle and its component parts.

   Q: What can happen to water after it falls to the ground as precipitation?
   A: Evaporate back into the atmosphere, be absorbed into the ground (infiltrate), or be carried along the surface of the ground as runoff.

2. Lead students to the first study site and ask them to write a description of the site on *Activity 2.5 Runoff Study Site Data Sheet* — Runoff Study Site 1.
3. Ask students to predict what they think will happen when heavy rain falls on the site, and have students record their predictions on the data sheet.
4. Have one student pour 2 liters of water in one location in the study site and observe what happens. Have students complete the "Site 1 Observation" section of the data sheet.
5. Lead students to the second study site and repeat the procedure. Instruct students to complete the data in *Activity 2.5 Runoff Study Site Data Sheet* — Runoff Study Site 2.

Activity 2.5 Runoff Study Site Data Sheet

Runoff Study Site 1

At each site, complete a site description and predict how much runoff will occur. Then test your prediction and record the results.

Site 1 Description
Elevation (flat, slight slope, steep slope):
Surface (cement, asphalt, sand, topsoil, etc.):
Vegetation (covered with plants, few plants, no plants):
Location (open/exposed or shaded/protected):

Site 1 Prediction
What do you think happens when heavy rain falls on this site?

Site 1 Observation To test your prediction, pour 2 liters of water over the same spot in your site. Observe and describe what happens.
Observations:
How much water was absorbed by the ground? (some, all, none) This is infiltration.
How much water ran off the surface? (some, all, none) This is runoff.
Was your prediction supported by your findings?

Runoff Study Site 2

At each site, complete a site description and predict how much runoff will occur. Then test your prediction and record the results.

Site 2 Description
Elevation (flat, slight slope, steep slope):
Surface (cement, asphalt, sand, topsoil, etc.):
Vegetation (covered with plants, few plants, no plants):
Location (open/exposed or shaded/protected):

Site 2 Prediction
What do you think happens when heavy rain falls on this site?

Site 2 Observation To test your prediction, pour 2 liters of water over the same spot in your site. Observe and describe what happens.
Observations:
How much water was absorbed by the ground? (some, all, none) This is infiltration.
How much water ran off the surface? (some, all, none) This is runoff.
Was your prediction supported by your findings?

Teacher Preparation — Part 2 Student-Made Erosion Models

During this second activity, students will explore and test methods for preventing erosion using simulations. This activity may be conducted as a single class demonstration or in groups of 3–5 students. Three plastic shoeboxes will be used for the demonstration (or for each group of students). Prepare the shoeboxes to drain water by drilling 3–5 1/4 inch drainage holes in the bottom edge of one end of each shoebox (see illustration on *Activity 2.5 Part 2 Erosion and Runoff Model Instruction Sheet*). Drill holes close enough together to ensure that water will drain into the beaker or measuring cup. Gather and arrange the remainder of materials for each group.

This activity may be conducted as a single class demonstration or in groups of 3–5 students.

Materials

(number of items are for a single class demonstration of erosion and runoff simulation, or for each group of students)

- ➤ Student science notebooks
- ➤ Pencils
- ➤ *Activity 2.5 Erosion and Runoff Model Data Table* (included in student science notebook)
- ➤ *Activity 2.5 Part 2 Erosion and Runoff Model Instruction Sheet* (one per group)
- ➤ 3 plastic shoeboxes of the same size
- ➤ Soil (locally gathered soil offers the best demonstration; potting soil is too loosely packed)
- ➤ Sod (or sponges and mulch, grass clippings, or sphagnum moss)
- ➤ Watering can with sprinkling head
- ➤ 3 beakers or measuring cups (at least 350 mL)
- ➤ 3 blocks of wood to place under one end of the shoeboxes to make a slope
- ➤ 2 stopwatches
- ➤ Drill with 1/4-inch bit to make drainage holes in plastic boxes.

Procedure

1. Review the following terms in student book on pages 11, 14, and 15.
   - Runoff — Water from precipitation that flows over the surface of the ground and eventually makes its way to a body of water. Runoff can pick up soil and pollutants from the land and carry them to a body of water such as a stream, lake, or wetland.
   - Weathering — The process by which solid rock is broken into smaller pieces.
   - Erosion — The process that carries away bits of rock and soil.
   - Infiltration — When water soaks into the ground. Once in the ground, this water can be used by the roots of plants or stored in the groundwater system.
   - Impermeable surface — A surface that does not allow water to soak in or to pass through.
2. Guide students in creating erosion and runoff models following the procedures included on the *Erosion and Runoff Model Instruction Sheet*.
3. Guide students in completing the *Erosion and Runoff Model Data Table*, included in their science notebooks.

Activity 2.5 Part 2 Erosion and Runoff Model Instruction Sheet

1. Set the shoeboxes on a table and put pieces of wood under the boxes so they are on a slope with the drain holes on the lower end. The end of the box with the drain holes should hang slightly over the end of the table. Hold a beaker or measuring cup under the drain holes during the simulation (see illustration). Another option is to place the shoebox on a higher surface so that the beaker or measuring cup may be placed on the table, below the drain holes.
2. Prepare each of the shoeboxes in the following manner:
   - Fill Box 1 with soil only. This represents bare soil.
   - Fill Box 2 with a piece of sod. If sod is not available, use sponges (representing roots), followed by soil and then topped with mulch, grass clippings, or sphagnum moss. This represents land that is covered in vegetation.
   - Fill Box 3 with soil and then cover it with plastic wrap or aluminum foil so that very little soil is exposed. This represents impermeable surfaces such as roads, parking lots, and rooftops.
3. Put together the experiment as shown in the illustration.
4. Measure 350 mL of water with one of the beakers or measuring cups and pour it into the watering can. This will be the water you will pour onto the surface of the box. Record this amount in the appropriate place on the data table.
5. Assign roles to each student in a group:
   - Rain simulator — in charge of measuring and pouring water into the box.
   - Stop watcher 1 — in charge of timing the soak-in time. Start when the water falls onto the surface and stop when the water begins to flow out through the drain holes.
   - Stop watcher 2 — in charge of timing the runoff time. Start when water begins flowing through the drain holes and into the beaker or measuring cup and stop when water no longer flows into the measuring cup in a steady stream but starts to drip.
6. Once everyone has a clear idea about what they will be doing, run the experiment by pouring the water onto the surface of the "bare soil" box and begin timing what happens next.
7. Record the times in the appropriate places in the data table.
8. Measure and record the amount of water that is present in the measuring cup.
9. Estimate the amount of soil erosion by observing any soil in the water in the measuring cup.
10. Repeat the steps for the remaining two surface types.
11. Record your measurements in the data table and then use your data to answer the questions.

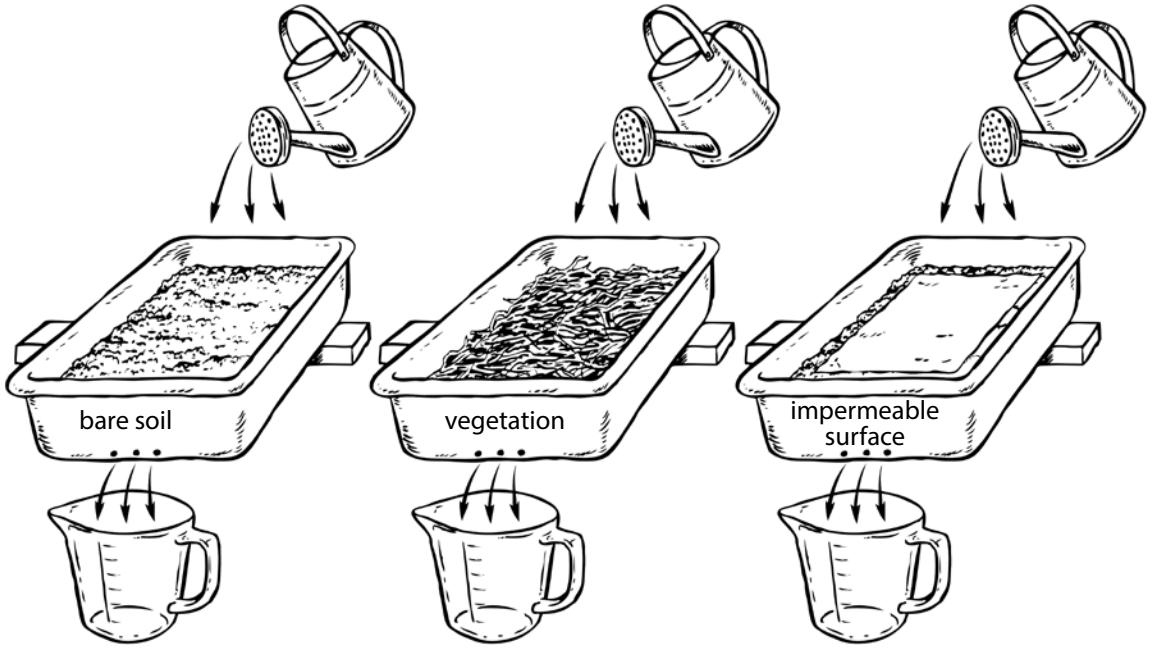


ILLUSTRATION: MARK RAITHEL

Activity 2.5 Erosion and Runoff Model Data Table

Data	Land Surface Type		
	Bare Soil	**Soil with Vegetation**	**Impermeable Surface**
Water Input (mL)			
Soak-in Time (seconds)			
Runoff Time (seconds)			
Water Output (mL)			
Soil Erosion (none, a little, a lot)			

1. Which of these surfaces had the most erosion? _____
   Describe how you know. _____
   _____
   _____
   _____

2. Figure out how much water each of the surfaces held by comparing how much water you put in with how much water came out. Which of these surfaces held the most water?
   _____
   _____
   _____

3. Which of these surfaces held the least water? _____
   _____
   _____
   _____

4. For the next two questions, calculate the runoff rate and enter it in the table below. The runoff rate is the water output (volume) divided by the time of runoff. Units are milliliters/seconds.

Bare Soil	Soil with Vegetation	Impermeable Surface

5. Which of these surfaces had the fastest runoff rate (greatest volume of water/second)?
   _____
   _____

6. Which of these surfaces had the slowest runoff rate (least volume of water/second)?
   _____
   _____

Wrap-up

After groups have completed their data sheets and data tables, conduct a class discussion.

Q: How is the experiment similar to what happens in a watershed?
A: The watering can represents precipitation. The boxes represent the Earth's surface and illustrate how water can either infiltrate or run off. The beaker represents a type of water body such as a stream, river, lake, or wetland.

Q: How does the slope of an area affect the amount of surface water runoff?
A: The greater the slope, the greater the potential for surface water runoff.

Q: How does the amount of vegetation in an area affect the amount and quality of surface water runoff?
A: Vegetation reduces surface water runoff by slowing down water and allowing it to soak into the ground where it can be used by plants or stored in the soil and/or groundwater. Leaves reduce weathering and erosion by reducing the impact of water drops striking the soil. Roots act like sponges that soak up water and store it. Vegetation can also help filter water of pollutants that might be in runoff.

Q: How do impermeable surfaces affect the amount of surface water runoff?
A: Impermeable surfaces can increase runoff because they prevent water from soaking into the ground. Impermeable surfaces on slopes provide little friction for slowing moving water.

Q: What do you think might happen if great amounts of runoff suddenly entered a stream?
A: Runoff can carry soil particles and pollutants into a stream. It can also increase the volume and speed of stream flow and increase erosion along stream banks.

Q: How does runoff affect water quality?
A: Runoff containing lots of soil particles can make a stream or lake cloudy. Water loaded with soil particles can harm fish and other aquatic organisms by clogging gills and decreasing the amount of sunlight needed for aquatic plants to produce oxygen needed by other aquatic organisms. Runoff can also carry pollutants into bodies of water.

Q: Can you think of a way we could change the experiment to show representations of different types of pollutants on the impermeable surfaces?
A: Perhaps put food coloring droplets on the covering over the soil on the impermeable box.

Q: What can we do in our schoolyard and community to reduce erosion due to runoff?
A: Cover exposed slopes and bare soil with vegetation. Reduce the amount of impermeable surfaces. Install rain gardens. Use storm water control measures such as retention basins. In crop fields, use no-till planting, terraces, grass waterways, cover crops, and strip cropping.

Note: As a low-cost alternative to plastic shoeboxes, empty 2-liter soda bottles can be used in place of plastic boxes. Cut bottles in half vertically, while leaving neck intact. The bottle will be placed on its side to hold soil for simulation.

Taking It Home

Have students refer to Page 13 in their student books for information on storm drain stenciling. Encourage them to contact local water service departments in their neighborhood for more information on how pollutants can travel through runoff and to find out if they are aware of storm drain stenciling projects. Some cities may be open to having students stencil storm drains, especially in the neighborhoods surrounding the school. Visit **mostreamteam.org** for more information.

Activity 2.6 Erosion in a Stream Table

Estimated Time

(1) 50-minute class period

Learning Standards

MLS: 6-8.ESS2.A.2
NGSS: MS-ESS2-2

Objectives

Students will be able to:

1. Develop or use a model of a stream to make and record observations.
2. Observe the effects of moving water and gravity in the geoscientific process of erosion.
3. Construct an explanation based on evidence on how the geoscientific process of erosion has shaped the Earth.

Teacher Preparation

Erosion is one of the processes by which the Earth is shaped. In this activity, students will use a stream table to develop a model that demonstrates the force of gravity, moving water, and the role they play in erosion. Students will then construct an explanation based on their observations (evidence) on how erosion, a geoscientific process, has changed Earth's surface.

Stream tables are available for purchase, or they may be available for loan from county, state, or federal agencies. Stream tables may also be constructed using materials commonly found at hardware and home improvement stores.

Materials

- Student science notebooks
- Pencils
- *Stream Anatomy Reference Sheet*
- *Stream Anatomy Assessment Sheet* (optional)
- Stream table
- Stream medium (sand or recycled plastic particles)
- Water source

Procedure

1. Have the students place the stream table on a slight incline with the high end approximately 1 to 2 inches off of the table. Fill the stream table with the stream medium. Explain to the students that the stream table is a model of the Earth's surface and that they are going to observe how erosion shapes the Earth through the forces of moving water and gravity.
2. Have the students create, in their student science notebooks, a simple sketch and written description of the stream table. On the lined portion of the notebooks, have students make a prediction as to what they think will happen when water is added to the top of the table. Provide the students with the *Stream Anatomy Reference Sheet* and discuss stream anatomy and vocabulary.
3. When the students have completed making their predictions, have a student slowly begin to add the water from the top of the stream table.

4. Once a stream or streams begin to form, stop adding water and have the students sketch the stream table from a top view. Ask the students to label the stream parts in their notebooks based on their observations. If they cannot identify all the parts, continue to add water in increments until they can observe the formation of all or most parts of the stream.

   Q: What is happening as the water flows down the stream table?

   A: The force of gravity is pulling the water downhill. As the water moves over the stream table, the water picks up and moves pieces of stream medium, carrying it downstream as it carves out a stream channel. The stream table is modeling the geoscientific process known as erosion.

5. Explain to the students that they are going to change the setup of the table. Ask students what they think will happen when they increase the incline of the table. Have students make predictions in their notebooks and then raise the table by 1 to 2 inches. Add water at the same volume and from the same place as before. After a minute or two, stop the flow of water and give the students an opportunity to discuss and record their observations.
6. Repeat the process above by having the students make changes to the stream table by increasing the incline, increasing the amount of water being added to the table, or lengthening the time to allow more water to flow. Repeat the process, being sure to check with the students before and after each change, allowing them to make predictions and discuss the results.

Wrap-up

During the activity, students collected evidence in the form of observations, recording of notes, and sketches. Using this evidence, have the students construct an explanation of how the geoscientific process of erosion can change the Earth's surface.

Included at the end of this activity is an unlabeled *Stream Anatomy Assessment Sheet* that can be used as a check for comprehension of stream anatomy terms and processes. The page may be copied for each student or used in an interactive format on a smart board.

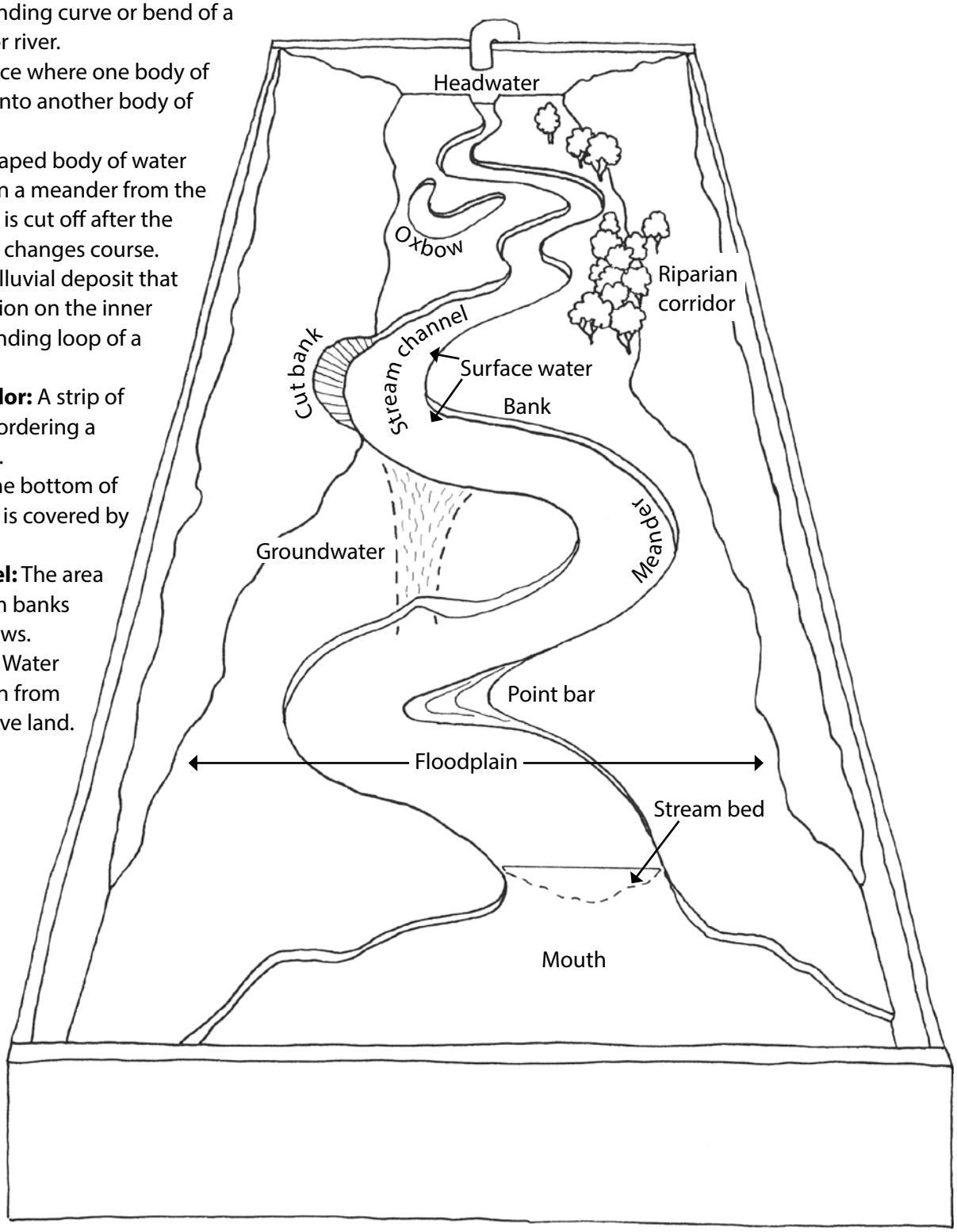
Cross-Curricular

Provide each student two transparency sheets. Explain to students that they are to create two different stream drawings, one on each sheet. One stream drawing should depict a stream with vegetated banks and riparian corridor that is less prone to bank erosion. The second transparency will depict the same stream channel without erosion-control features. Drawings should also reflect differences in aquatic life. Have students overlay their transparencies to demonstrate how a stream changes due to erosion.

Activity 2.6 Stream Anatomy Reference Sheet

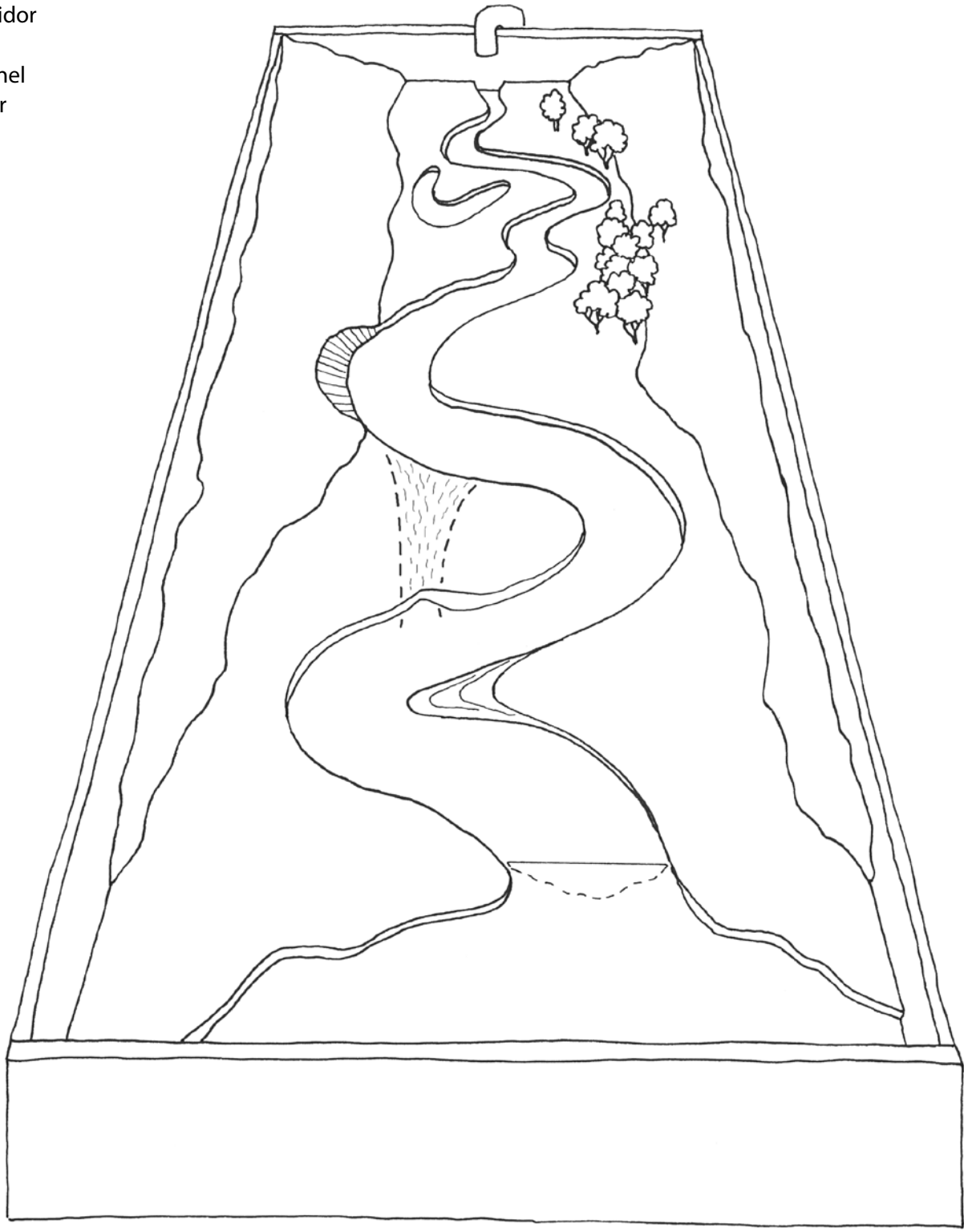
Listed below are terms for stream anatomy. Students should label the anatomy of the stream in their notebooks as they conduct the activity.

Bank: The land along a stream, between the water and the upland areas.
Cut bank: The outside bank of a water channel (stream), which is continually undergoing erosion.
Floodplain: An area of low-lying ground adjacent to a river, formed mainly of river sediments and subject to flooding.
Groundwater: Water that is collected or flows beneath the surface of the ground.
Headwater: The source of a river or stream.
Meander: A winding curve or bend of a creek, stream, or river.
Mouth: The place where one body of water empties into another body of water.
Oxbow: A U-shaped body of water that forms when a meander from the stream channel is cut off after the stream channel changes course.
Point bar: An alluvial deposit that forms by accretion on the inner side of an expanding loop of a river.
Riparian corridor: A strip of forested land bordering a stream channel.
Stream bed: The bottom of the stream that is covered by water.
Stream channel: The area between stream banks where water flows.
Surface water: Water that can be seen from the surface above land.



Activity 2.6 Stream Anatomy Assessment Sheet

- Bank
- Cut bank
- Floodplain
- Groundwater
- Headwater
- Meander
- Mouth
- Oxbow
- Point bar
- Riparian corridor
- Stream bed
- Stream channel
- Surface water



Activity 2.7 Turbidity

Estimated Time

(1) 50-minute class period

Learning Standards

MLS: 6-8.ESS2.A.2
NGSS: MS-ESS2-2

Objectives

Students will be able to:

1. Measure the turbidity of a sample of water.
2. Explain how turbidity is related to erosion and water quality.
3. Observe and explain the cause and effects of turbidity and research possible ways to reduce turbidity in our waterways.

Teacher Preparation

Turbid water primarily results from erosion and runoff and also from the disturbance of benthic sediment. While there are areas (such as larger rivers) that are naturally more turbid, excessive turbidity is typically detrimental to aquatic ecosystems. Some animals are adapted for naturally turbid environments. For example, catfish use barbels and their sense of smell to find food in turbid waters where other fish will not venture. When turbidity levels are unnaturally high, water quality decreases and aquatic organisms that require more clear water are negatively affected.

Turbidity is measured by determining the amount of light transmitted through water. As the number of particles of solid matter in water increases, less light passes through, so the maximum depth at which you can see objects beneath the water's surface decreases.

Turbidity tubes can be used to measure turbidity in streams or from the edge of a lake or pond. The tube is filled with water and then slowly drained until the black and white pattern becomes discernible through the column of water. The reading is then made in centimeters along the side of the tube. Some tubes are graduated in Nephelometric Turbidity Units (NTU). Turbidity can also be measured in Jackson Turbidity Units (JTU). In this test, comparisons are made between the sample and a known measure, or by adding a reagent solution. The JTU method works well for relatively small samples of water.

Students will use a basic water testing kit and/or a transparency/turbidity tube to measure the turbidity of water they have collected from the schoolyard or from samples you have brought in. If you are planning a trip to a pond or a lake, and you have access to a bridge or walkway, you may want to purchase and follow directions for using a Secchi disk, which is designed to be lowered into deep water to measure turbidity.

Sources (causes) of excess turbidity in streams include:

1. The majority of suspended sediment present in water comes from erosion and runoff. Erosion and runoff of soil can be a result of development, construction, and other land disturbance.
2. Quarries and gravel mining operations can result in fine sediment entering a stream and smothering habitat.
3. Agricultural areas not under best management practices to prevent soil erosion can cause sediment to run into local bodies of water.
4. Nutrients from fertilizers encourage algae to grow excessively in the water, which increases dissolved oxygen. However, when the algae die, the organic material is decomposed by microbes in the water. This decomposition process can decrease dissolved oxygen levels to below-normal levels.

Impacts (effects) of unnaturally high levels of turbidity include:

1. Sediment blocks light needed for vegetation to photosynthesize.
2. Suspended particles absorb heat and increase water temperature.
3. Particles in turbid water provide attachment places for pollutants like metals and bacteria.
4. An increase in sedimentation and siltation can clog fish gills and bury their eggs. Fish that hunt by sight and speed to catch their prey are especially affected by high turbidity levels.
5. High turbidity can also reduce aquatic habitat and smother invertebrates such as freshwater mussels.

Materials

- ➤ Student science notebooks
- ➤ Pencils
- ➤ Thermometers for measuring air and water temperatures
- ➤ Containers for collecting water samples
- ➤ Basic water testing kit that includes equipment for testing turbidity or transparency
- ➤ Turbidity tube (optional); to create your own, visit **youtu.be/IxU2fcKk3Jw**

Procedure

1. Have students complete their science notebook headings and take and record outdoor air temperature.
2. Have students collect water samples from three sources — a faucet and two other places from the schoolyard (for example, a ditch, puddle, or water feature). Alternatively, the teacher or students could collect three water samples from other places and bring them to school.
3. Label water samples 1, 2, and 3. Have the students observe the water samples and predict their water quality. Record in their science notebooks which sample they think has the highest turbidity and the least turbidity.
4. Have students measure the turbidity of the water samples using the instructions from the basic water testing kit or turbidity tube. Ask students to compare their predictions with their test results, and record these in their science notebooks.
5. Discuss turbidity and water quality with the students. In general, the higher the turbidity, the lower quality of water for living organisms. However, there are exceptions.

Q: Explain why water that appears clean may have poor quality for some living organisms.
A: Water that appears clear and clean may contain many dissolved pollutants that are harmful to living organisms. Heavy metals, pesticides, chlorine, and other toxic chemicals may not show up in turbidity testing. Certain pathogens — bacteria, viruses, parasites — that could make you very sick may be present, as well. Do not drink water — even clear water — unless it has been treated!

Q: Explain why water that appears dirty may have good quality for some living organisms.
A: Nutrient-rich sediments in flood water are deposited in the floodplains and wetlands (aquatic to terrestrial); while nutrients are provided to the aquatic systems in the form of leaves, woody debris, and other materials (terrestrial to aquatic). Although these waters may appear dirty, healthy stream systems are connected to terrestrial systems and an exchange of nutrients between the environments create a natural balance. Some animals, such as catfish, are more adapted to compete for food in turbid water.

Q: What are some naturally occurring events that could increase water turbidity?
A: Weather can increase turbidity of water as storms move through an area. Erosion of stream banks, riparian zones, and stream channel movement will increase water turbidity. Natural decomposition of organic matter like leaves can also increase turbidity.

Q: Which organisms in a river or stream might be affected as the sediment settles out of the turbid water?
A: Benthic or bottom-dwelling animals like macroinvertebrates, mussels, some fish, and aquatic plants.

Q: How could these organisms be negatively affected?
A: Sedimentation and siltation can clog gills of macroinvertebrates and fish. It can also smother eggs of fish and amphibians and can reduce habitat for freshwater mussels. Aquatic plants may be smothered, too.

Q: What can be done to reduce turbidity?
A: Many of the causes of turbidity can be reduced by humans using better environmental practices in agriculture, in construction, and at home.

Wrap-up

In discussion and in their science notebooks, have students explain the meaning of turbidity.
Have students describe how to measure turbidity.

Assessment

Explain the cause and effect of turbidity in rivers and streams.
Describe and explain some ways to decrease turbidity in streams and rivers.

Resources

- **mostreamteam.org/Documents/Fact%20Sheets/FactSheet2WWW.pdf**
- Murdoch, Tom, Martha Cheo with Kate O'Laughlin. 1999. A Streamkeeper's Field Guide: Watershed Inventory and Stream Monitoring Methods. Everett, WA: The Adopt-A-Stream Foundation.
- Bryan, Virginia, Allen Burbank, Jack Ballinger. 1995. Rivers Curriculum Guide Chemistry. Parsippany, NJ: Pearson Learning Group

Cross-Curricular

Have students research human environmental practices in agriculture, construction, and even in homes that contribute to an increase in turbidity of local bodies of water.

Choosing one such human practice, have students write a persuasive argument for the discontinuation of or reduction of such practice. Have students include suggested alternative practices that could be used without contributing to the turbidity of nearby water.

3 MATTER and Energy

Estimated Time

(8) 50-minute class periods

Vocabulary

Carnivore
Cellular respiration
Consumer
Decomposer
Food chain
Food web
Herbivore
Nutrient
Omnivore
Photosynthesis
Phytoplankton
Primary consumer
Producer
Scavenger
Secondary consumer

Activities

3.1 Physical and Chemical Hike
3.2 Photosynthesis Investigation
3.3 Aquatic Food Chains and Food Webs
3.4 Go with the Flow — Energy Flow in Food Chains
3.5 Classroom Composting
3.6 Photosynthesis Model Relay

Missouri Learning Standards

6-8.PS1.A.2 Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.
6-8.PS1.B.1 Develop and use a model to describe how the total number of atoms remains the same during a chemical reaction and thus mass is conserved.
6-8.LS1.C.1 Construct a scientific explanation based on evidence for the role of photosynthesis and cellular respiration in the cycling of matter and flow of energy into and out of organisms.
6-8.LS2.B.1 Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem.

Next Generation Science Standards

Performance Expectations

(Science and Engineering Practices underlined)
MS-PS1-2 Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.
MS-PS1-5 Develop and use a model to describe how the total number of atoms does not change in a chemical reaction and thus mass is conserved.
MS-LS1-6 Construct a scientific explanation based on evidence for the role of photosynthesis in the cycling of matter and flow of energy into and out of organisms.
MS-LS1-7 Develop a model to describe how food is rearranged through chemical reactions forming new molecules that support growth and/or release energy as this matter moves through an organism.
MS-LS2-3 Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem.

Disciplinary Core Ideas

PS1.B: Chemical Reactions

- The total number of each type of atom is conserved, and thus the mass does not change. (MS-PS1-5)
- Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants. (MS-PS1-2), (MS-PS1-5)

LS1.C: Organization for Matter and Energy Flow in Organisms

- Plants, algae (including phytoplankton), and many microorganisms use the energy from light to make sugars (food) from carbon dioxide from the atmosphere and water through the process of photosynthesis, which also releases oxygen. These sugars can be used immediately or stored for growth or later use. (MS-LS1-6)
- Within individual organisms, food moves through a series of chemical reactions in which it is broken down and rearranged to form new molecules, to support growth, or to release energy. (MS-LS1-7)

LS2.B: Cycle of Matter and Energy Transfer in Ecosystems

- Food webs are models that demonstrate how matter and energy is transferred between producers, consumers, and decomposers as the three groups interact within an ecosystem. Transfers of matter into and out of the physical environment occur at every level. Decomposers recycle nutrients from dead plant or animal matter back to the soil in terrestrial environments or to the water in aquatic environments. The atoms that make up the organisms in an ecosystem are cycled repeatedly between the living and nonliving parts of the ecosystem. (MS-LS2-3)

Crosscutting Concepts

Patterns

- Macroscopic patterns are related to the nature of microscopic and atomic-level structure. (MS-PS1-2)

Energy and Matter

- Matter is conserved because atoms are conserved in physical and chemical processes. (MS-PS1-5)
- Within a natural system, the transfer of energy drives the motion and/or cycling of matter. (MS-LS1-6)
- Matter is conserved because atoms are conserved in physical and chemical processes. (MS-LS1-7)
- The transfer of energy can be tracked as energy flows through a natural system. (MS-LS2-3)

Activity 3.1 Physical and Chemical Hike

Estimated Time

(1) 50-minute class period

Learning Standards

MLS: 6-8.PS1.A.2, 6-8.PS1.B.1
NGSS: MS-PS1-2, MS-PS1-5

Objectives

Students will be able to:

1. Distinguish the difference between a physical and chemical reaction.
2. Observe examples of reactions (or evidence of reactions) that occur in nature and identify whether each example is a physical or chemical reaction.
3. Explain how to determine if a chemical reaction has occurred.

Teacher Preparation

This activity provides an opportunity for students to review the differences between physical and chemical properties and reactions, and it reinforces concepts that will help students understand photosynthesis, decomposition, and energy transfer.

Take a preparatory walk around the schoolyard and note where you find examples of physical or chemical reactions or evidence of reactions. Some examples include cut grass, concrete sidewalks, rust on or around railings, animal droppings, chewed leaves, rotting logs, broken tree limbs, cars burning gasoline, evidence of photosynthesis, spider silk, burned wood, and birds eating. During the activity, provide subtle prompts if students are unsure how or unable to find examples of reactions on their own.

Materials

- Student science notebooks
- Pencils
- Air thermometers
- Magnifiers

Procedure

1. Have students bring their science notebooks, pencils, thermometers, and magnifiers into the schoolyard. Instruct students to complete their science notebook headings and take and record the outdoor air temperature.
2. Explain that students will explore the schoolyard and use observation skills to identify examples of physical and chemical reactions. Explain that some objects the students discover will have chemical reactions occurring as they watch, while others objects may only show clues about reactions that occurred in the past or may occur in the future.

3. Discuss the differences between physical and chemical properties and reactions.

   Q: What are some physical properties of matter?
   A: Color, texture, density, mass, volume, physical dimensions, etc. Physical properties can be observed or measured without changing the chemical makeup or composition of the substance.

   Q: What is a physical reaction?
   A: A physical reaction is a change in which the object (matter) may look different, but its chemical composition stays the same. An example is freezing water in a pond. The water may change its state and appearance, but it is still water.

   Q: What are chemical properties of matter?
   A: A chemical property is the ability of a substance to combine with or change into one or more other substances. Measuring or testing a chemical property must lead to a change in the substance's chemical composition.

   Q: What is a chemical reaction?
   A: A chemical reaction is a change in which one or more kinds of matter are transformed to new kinds of matter with different compositions. The bonds between atoms are broken and created to form new molecules. An example is photosynthesis, in which carbon dioxide and water transform inside a plant leaf in the presence of sunlight to produce different compounds (sugars and oxygen). Other examples include reactivity, flammability, and the ability to rust.

   Q: How can you tell if something is undergoing or has undergone a chemical reaction?
   A: Since chemical reactions require changes at the molecular level that we cannot see, we have to rely on other pieces of evidence. Some clues that indicate a chemical reaction has probably occurred include a change in color, odor, or temperature, or giving off light or gas.

4. Explain that chemical reactions can release energy or store energy for later use. Food produced by a plant during photosynthesis can be used immediately or stored for later use. Similarly, food eaten by an animal is broken down and rearranged to form new molecules. These molecules may help the animal grow, give it energy to use right away, or be stored in the body as fat.

5. Before students hike, and as a group, have them look around and discuss an example or two:
   - Tree — a plant's mass comes from food it produced during photosynthesis. If the leaves are green, it is probably producing sugars right now.
   - Chewed leaves — although the plant suffered physical damage, the leaf parts are undergoing a chemical reaction in the gut of the caterpillar that ate them.
   - Animal droppings — evidence that the chemical reaction of digestion has occurred. Scat is waste to some animals but is a source of nutrients for scavengers and decomposers that will break it down further.
   - Other examples — spider webs, burned wood, broken tree limbs, fireflies, decomposition, soil, rocks, etc.

6. Instruct students to record examples of their physical and chemical discoveries in their notebooks. Each notebook entry should include:
   a) Sketch or description of the object discovered.
   b) Evidence that a physical or chemical reaction has occurred.
   c) Hypothesis about where energy came from before it reaches the object and where it will go after it leaves.
   d) Any questions students may have.

7. Give students instructions about their hike — where they should or should not go, how many should hike together, how much time they have, and where they should meet at the designated time.

Wrap-up

1. When students return to the classroom, ask for volunteers to share notebook entries to check for understanding.
2. List student questions on the board.
3. Have students discuss answers or how answers may be obtained.
4. Ask students if some reactions were difficult to label as physical or chemical. Why?
5. Ask students if weather conditions affected what they observed. How?

Assessment

List three of the chemical reactions that you observed on your hike. Explain how you know they were chemical reactions.

Cross-Curricular

Have students experiment with various art media, such as pastels, India ink, clay, etc. Discuss which art media demonstrate physical or chemical reactions when the media is mixed or used.

Examples:

- When a clay pot is fired, it undergoes both physical and chemical change.
- When India ink is placed over other media, such as chalk or crayon, a chemical change occurs with the underlying media.
- When dry or powdered watercolor paint is mixed with water, a physical change is made.

Activity 3.2 Photosynthesis Investigation

Estimated Time

(1) 50-minute class period

Learning Standards

MLS: 6-8.LS1.C
NGSS: MS-LS1-6, MS-LS1-7

Objectives

Students will be able to:

1. Make observations and collect data.
2. Explain the relationship between the amount of light and the amount of oxygen produced in photosynthesis.
3. Explain the role of photosynthesis in the cycling of matter and flow of energy into and out of organisms.

Teacher Preparation

Photosynthesis is a chemical reaction. Students should already be aware from other science lessons that several external factors can affect the rate of a chemical reaction. Students will investigate light as one factor and will identify the relationship between the amount of light and the amount of oxygen produced in photosynthesis.

Aquatic plants used in this activity may be collected from a local pond or lake, or they may be purchased from a pet store or biological supply company. All plants used in this activity should be the same species. Common pondweed is suitable, as is *Cabomba*, an aquarium plant commonly available in pet stores that sell aquarium supplies.

For each group of 3–4 students, you will need a beaker large enough to contain a submerged plant approximately 10 cm long. If clear 2-liter soda bottles are used, remove the label and cut the top off the bottle, removing the neck and shoulder from the bottle.

Note: Be sure to properly dispose of the plants used in this investigation by placing them in a closed garbage bag and depositing the bag in a dumpster. To prevent the spread of an invasive species of plant, do not dump the plants in or near any water source.

Materials

- Student science notebooks
- Pencils

For each group of students:

- *Activity 3.2 Photosynthesis Data Worksheet* (included in student science notebook)
- Stopwatch or timer
- 1 large beaker or clear 2-liter soda bottle (with top removed)
- 1 aquatic plant (approximately 10 cm long)
- 1 small rubber band
- 1 large nail, bolt, nut, washer, or rock heavy enough to keep the plant submerged
- 1 pair of scissors
- 1 bright desk lamp or aquarium light (UV works best)
- Metric ruler or tape measure

Procedure

Indoors

1. Divide students into groups of 3–4.
2. Explain the procedure to the class.
3. Have students open their science notebooks to *Activity 3.2 Photosynthesis Data Worksheet* and review the data chart.
4. Direct students to remove the roots from their group's aquatic plant, using scissors. The plant may also need to be trimmed so that it is small enough to remain submerged in the beaker or soda bottle.
5. Have students make an anchor for their plant, using the rubber band to fasten the nail, bolt, etc. to the bottom of the plant.
6. Direct students to place their plant in their beaker or soda bottle and fill the container with water. The plant should remain submerged at least 6 cm below the surface of the water.
7. Darken the room or have students move their plant and container to an area with low light. There should be enough light so students can count oxygen bubbles produced by the plant (if any.)
8. Direct students to start their timers and count the number of bubbles produced by their plant (if any) for one minute. Bubbles that are produced and stick to the leaves should be counted as well as bubbles that rise from the plant to the surface of the water.
9. Students should collect data and record them on the chart for Test 1: Trials 1, 2, and Average.
10. Have students arrange their plant so that it is 60 cm away from a bright desk lamp or aquarium light. Students should collect and record data for Test 2 on their charts.
11. Direct students to repeat data collection and recording for the other tests, arranging their plant so that it is 30 cm from the light source for Test 3 and 6 cm for Test 4.
12. In their groups, have students discuss the questions on the data worksheet and record answers.

Note: Adding baking soda (sodium bicarbonate, $NaHCO_3$) to the water to make a 1 percent solution may increase bubbling action.

Extension

1. Take a walk around the schoolyard and ask students to note where they think the most photosynthesis occurs. Have students write an explanation that might support their hypothesis.
2. Conduct an investigation, using students' hypotheses to determine where in the schoolyard the most photosynthesis is most likely to occur.

Note: Various online "virtual labs" demonstrate this process and can be investigated for various plant types.

Wrap-up

Direct students to write a paragraph in their science notebooks in which students identify factors that affect photosynthesis and explain the role photosynthesis plays in the lives of producers, consumers, and in food webs.

Refer students to turbidity discussions in *Activity 2.7 Turbidity*. Ask students to explain how turbidity affects photosynthesis.

Cross-Curricular

Have students complete leaf rubbings. Discuss the present color of their leaves and how a leaf's color or changing of color indicates the stage of photosynthesis throughout seasons.

Activity 3.2 Photosynthesis Data Worksheet

	Number of Bubbles per Minute	**Number of Bubbles per Minute**	**Average Number of Bubbles per Minute**
	Trial 1	*Trial 2*	*Average*
Test 1 Low light			
Test 2 Lamp distance from plant 60 cm			
Test 3 Lamp distance from plant 30 cm			
Test 4 Lamp distance from plant 6 cm			

Q: In which test were the most oxygen bubbles produced? The least?
A: Trials in test 4 should have produced the most bubbles. Trials in test one should have produced the least bubbles.

Q: Besides light, what else may have caused the difference in the number of bubbles produced between the tests?
A: Different amounts of carbon dioxide in the groups' beakers or soda bottles; different temperatures of the water; length of time required between the plant's exposure to light and its production of oxygen; etc.

Q: Where did the oxygen atoms originate?
A: From the water and carbon dioxide

Q: Besides water and light, what else is required for photosynthesis to occur?
A: Carbon dioxide

Q: Besides oxygen, what else is produced in photosynthesis?
A: Sugar

Q: How are sugars used by the plant?
A: They can be used immediately or stored for growth or later use.

Q: How are sugars used by other organisms?
A: When one organism eats another, the energy stored in the tissues is passed on to the consumer. This energy can be used immediately or stored for growth or other use.

Activity 3.3 Aquatic Food Chains and Food Webs

Estimated Time

(1) 50-minute class period

Learning Standards

MLS: 6-8.LS2.B.1
NGSS: MS-LS2-3

Objectives

Students will be able to:

1. Develop a model of a food chain to show how energy flows among living and nonliving parts of an ecosystem.
2. Link food chains to form food webs.

Teacher Preparation

Connect to prior learning by discussing:

1. A food chain, which shows how energy moves between organisms
2. A food web, which includes two or more connected food chains
3. Relationships between animals and plants in a habitat (producer, primary consumer, secondary consumer, tertiary consumer, predator, prey, herbivore, carnivore, omnivore, decomposer)
4. Relationships between living and nonliving parts of an ecosystem

Materials

- Student science notebooks
- Pencils
- *Activity 3.3 Aquatic Food Chains and Food Webs Student Worksheet* (included in student science notebook)

Procedure

Have students follow the instructions in *Activity 3.3 Aquatic Food Chains and Food Webs Student Worksheet* in their student science notebooks.

Wrap-up

After students have completed their worksheets, have a discussion with the class using the following questions:

Q: What is the difference between a food chain and a food web?
A: A food chain is a simple model that shows how energy moves from the sun to a producer and through various consumers. Food webs are more complicated models that show how different food chains are interconnected. Food webs often include scavengers and decomposers.

Q: What is the role of scavengers and decomposers in food webs?
A: Scavengers and decomposers break down organisms into smaller pieces and eventually into atoms and molecules that can be reused by plants during photosynthesis.

Q: Explain why in nearly every ecosystem there are more plants than herbivores, more herbivores than carnivores, and just a few top-level predators.
A: Only a small portion of the original energy from the sun passes from one organism to the next in a food chain. The more links in a food chain, the less energy is available to the final consumer.

Q: What roles do humans play in food chains and food webs?

A: Humans play a role as consumers of producers and other consumers. By understanding how food chains, food webs, and ecosystems function, humans can make good decisions about managing natural resources so food chains, food webs, and ecosystems remain healthy.

Cross-Curricular

Food chain collage

To further demonstrate food chains, students can create a collage of animals in a food chain. Using construction paper, students will create 3 animal cutouts (of head and open mouth of three animals) to demonstrate the flow of energy and "who eats whom," the largest predator in the food chain will be placed with head and open mouth. For symmetry of animal head/mouth cutouts, fold paper vertically, tracing one side of animal's head and then cutting it out. Unfolding reveals symmetrical head. Next, place the second largest animal's head/mouth inside the predator that would eat the next animal. Continue with 3 increasingly smaller animals. Glue onto large construction paper.

Activity 3.3 Aquatic Food Chains and Food Webs Student Worksheet

1. Work in pairs to select an aquatic habitat and discuss conditions that affect the plants and animals that live there. List one producer, primary consumer, secondary consumer, and decomposer to make a single food chain of organisms that live in that habitat.

   Habitat _____

   a. Producer _____

   b. Primary consumer _____

   c. Secondary consumer _____

   d. Decomposer _____

   e. Give an example of a species that could fit in more than one level.

2. Sketch your food chain on a blank sheet of your science notebook. Add arrows to show the flow of energy from one organism to the next. Label the organisms with common names. Refer to pages 20–21 in the *Nature Unhooked* student book.

3. Find another pair of students who have selected a habitat similar to yours. Work with the other two students to combine your food chains into a food web.

4. Sketch your food web on a blank sheet of your science notebook. Add arrows to show the flow of energy between organisms. Label the organisms with common names.

5. Add nonliving components to your food web. Label these components and show how atoms get reused, rearranged, and recombined over and over again among living and nonliving parts of your food web.

Activity 3.4 Go with the Flow — Energy Flow in Food Chains

Estimated Time

(1) 50-minute class periods

Learning Standards

MLS: 6-8.LS2.B.1
NGSS: MS-LS2-3

Objectives

Students will be able to:

1. Demonstrate how energy flows among organisms in an ecosystem.
2. Explain why energy transfer in a food chain is limited:
   - the amount of energy transferred in a food chain is approximately 10 percent at each trophic level.
   - approximately 90 percent of energy is used and/or lost as it passes from one trophic level to the next in the food chain.
3. Create a model to describe the cycling of matter and flow of energy.
4. Illustrate energy transfer between trophic levels.

Teacher Preparation

This activity gives students the opportunity to collaborate as a team to demonstrate that only a small amount of energy (approximately 10 percent) is passed from one trophic level to the next. Students develop understanding through hands-on activity, class discussion, analyzing data, and making conclusions.

Energy is transferred between trophic levels beginning with producers capturing the sun's energy during photosynthesis. Consumers use much of the stored energy in plants and animals as food for growth, survival, and reproduction. Some energy is consumed by decomposers. Some plant parts can't be digested by herbivores, leaving some unused plant energy to be deposited into the environment. Energy that cannot be used is released through aerobic respiration and waste. For example, plant cellulose and invertebrate exoskeletons are not easily digested and are excreted. As animals are consumed by other living things, the flow of energy continues.

Conduct this activity outdoors to avoid a wet classroom.

Materials

- Student science notebooks
- Pencils
- *Activity 3.4 Go with the Flow — Student Worksheet* (included in student science notebook)
- *Activity 3.4 Go with the Flow — Class Data Graph* (included in student science notebook)
- 2 plastic buckets for each team (one with a mark at 9 liters)
- 9 liters of water for each team
- 1 small paper cup with a small hole created in the bottom for each student
- Graduated cylinder for measuring water (one per team)
- Sharpie marker

Procedure

Part A Indoors

1. Review food chains and energy pyramids.
2. Have students complete Part A of Activity 3.4 in their science notebooks.

Part B Outdoors

3. Divide students into groups, ranging from 3–8 students per group. This sets up food chains of varying lengths to demonstrate the inverse relationship between the number of links in the food chain and the amount of energy available at the end of the chain.
4. Assign one student in each group to be a producer and the other students as consumers in increasing trophic levels (primary consumer, secondary consumer, and so forth).
5. Each food chain will need 2 buckets. Mark 1 bucket with a marker at 9 liters.
6. Instruct students to form a line representing a food chain, beginning with a producer and ending with the top consumer. Have students stand approximately 10 feet apart.
7. Have one member from each food chain fill the marked bucket with 9 liters of water.
8. Place the bucket with 9 liters of water at the beginning of the chain, near the producer.
9. Place the empty bucket at the end of the line, by the last consumer.
10. Give one paper cup to each student.
11. Instruct the producer to fill his or her paper cup with water from the bucket, walk quickly to the next person in the food chain, and pour the water into that person's cup. Students may not block the hole in the bottom of their cup.
12. Students should continue transferring water through the food chain until the last consumer in the food chain empties his or her cup into the bucket at the end of the chain.
13. Repeat the steps, simulating transfer of energy, until the 9 liters of water is gone.
14. Students will lose most of their water as they walk quickly and pour, and as it drips from the bottom of the cup. This represents the energy lost during transfer from one trophic level to the next.
15. Instruct students to use graduated cylinders to measure the amount of water in the bucket at the end of the food chain.
16. Have students complete *Part B Group Data Sheet*.
17. Have students complete the *Class Data* table. In the "No. of Links" column, have students enter the number of links each group had, in order, 3–8. Ask each group to repeat its data so that all students may complete their *Class Data* tables.
18. Using data from the *Class Data* table, have students label each axis and graph the number of links and the percent of efficiency on the *Go with the Flow — Class Data Graph*.
19. Direct students to analyze their data and make conclusions about energy flow and transfer in food chains.

Wrap-up

Q: What did water represent in this lab?
A: Energy transfer from one trophic level to the next.

Q: How does a plant receive energy?
A: Plants capture the sun's energy during photosynthesis.

Q: How did the number of links in the food chain affect the efficiency of the food chain?
A: Just as water was spilled from container to container, so energy is lost from one trophic level to the next. The more links in a food chain, the less energy remains for higher trophic levels.

Q: If a mink ate a fish that fed on algae, what type of consumer would the mink be?
A: The mink would be a secondary consumer. The fish would be the primary consumer. Primary consumers eat producers; secondary consumers eat primary consumers.

Assessment

Have students write a paragraph using supportive data from the activity that explains energy transfer in an ecosystem.

Cross-Curricular

To further illustrate energy transfer in an ecosystem, have students create an energy model illustration, complete with drawings of organisms from each trophic level and supportive data from the activity.

Activity 3.4 Go with the Flow — Student Worksheet

Students _____

Names of team members

Part A

1. Draw a food chain below using these four organisms: bullfrog, small fish, river otter, algae

2. Draw a model to show energy transfer with these same organisms.

3. Assume that 10 percent of energy is passed from one trophic to the next. If the algae captured 20,000 calories of energy from the sun, how much energy would be available at each level above? Label these energy values on your model.

Part B
Group Data

Initial Amount of Water: 9,000 mL

Amount of Water Remaining: _____

Amount of Water Lost: _____

Formula to Determine Percent Efficiency:

Your Efficiency — Show Work Here

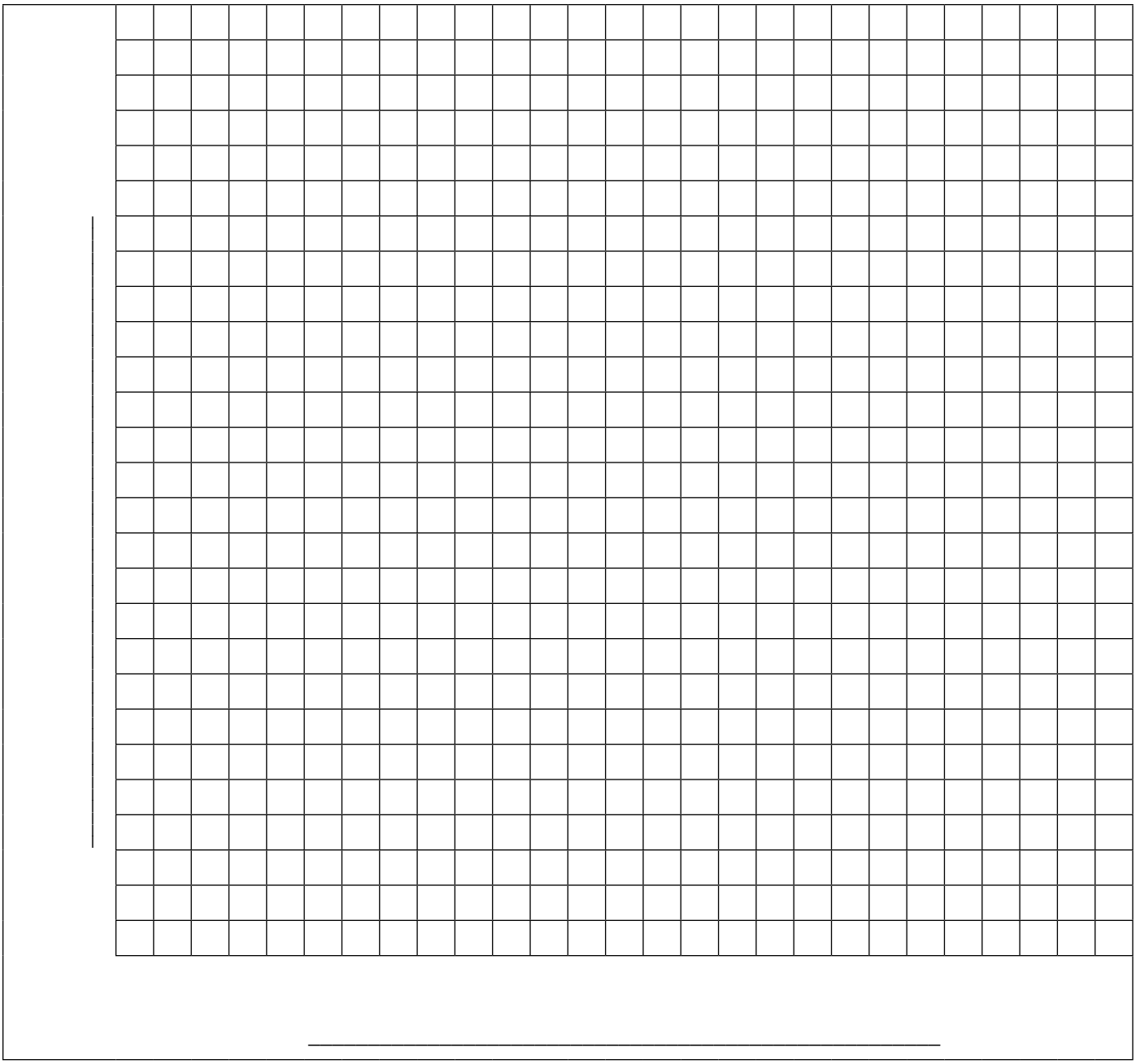
$$\textit{Percent Efficiency} = \frac{\textit{Amount of Water Remaining}}{\textit{Initial Amount of Water}} \times 100 = \_\_\_\_\_ \textit{ Percent}$$

Class Data

No. of Links	Amount of Water Remaining (mL)	Percent Efficiency	Average Efficiency if More Than One Group
3			
4			
5			
6			
7			
8			

Activity 3.4 Go with the Flow — Class Data Graph

Graph: Make a line graph below showing the number of links on the **x** axis (independent variable) and percent efficiency on the **y** axis (dependent variable). Extrapolate the line to show the maximum number of links in your food chain.



Analysis: Explain the meaning of your graph in three sentences below:

1.

2.

3.

Activity 3.5 Classroom Composting

Estimated Time

(1) 50-minute class period to construct
4–6 weeks of observation (5 minutes each day)

Learning Standards

MLS: 6-8.PS1.B1
NGSS: MS-PS1-5

Objectives

Students will be able to:

1. Recognize that some chemical reactions release energy while others store energy.
2. Explain how biological activity in a compost pile involves chemical reactions that increase heat.
3. Describe why decomposition is important and where it happens in nature.
4. Relate composting to the concept of recycling.

Teacher Preparation

You will need three 2-liter soda bottles for each group of students. For safety reasons, you may want to use a utility knife to make a slit at the places on the bottles where the students need to cut with their scissors.

Materials

- Student science notebooks
- Pencils
- Three 2-liter soda bottles for each group
- Utility knife
- Scissors
- Transparent packaging tape
- Blank labels
- Sharpie markers
- Thermometers
- pH paper (optional)
- One piece of nylon stocking for each tower — enough to fit over opening of soda bottle
- Rubber bands
- Soil (slightly moistened, in a tub with a scoop or trowel)
- Tub for mixing materials together
- Grass clippings or leaves
- Earthworms (a few for each tower, from garden, yard, or bait shop)
- Bulking agent (to provide air flow)
  - Wood shavings
  - Newspaper strips
  - Pieces of paper egg cartons
  - Chopped straw
- Food for the microbes (chopped up is best)
  - Lettuce scraps
  - Carrot peelings
  - Apple cores
  - Banana peels
  - Grass clippings or weeds

Note: Some organic wastes that should not be composted include:

- Meat, fish, or dairy products
- Diseased or insect-infested plants
- Weeds gone to seed
- Weeds that spread by runners (morning glory, quack grass, Indian strawberry, etc.)
- Dog and cat waste
- Large branches
- Pressure-treated, painted, or preserved lumber

Procedure

Compost Tower Assembly Instructions

1. Remove labels from all three bottles.
2. Refer to the illustration to determine where to cut the bottles.
3. Place the bottle on its side against the side of a box lid. The lid to a box of paper works well.
4. After marking the bottles, use a utility knife to start to cut a slit, and then finish cutting with scissors.
5. Put a piece of nylon stocking over the spout of bottle 2 (see bottle illustration) and secure it with a rubber band. This is for air flow.
6. Assemble the composting tower as shown in the bottle illustration. Leave the top off, so you can fill your tower. Tape the seams.

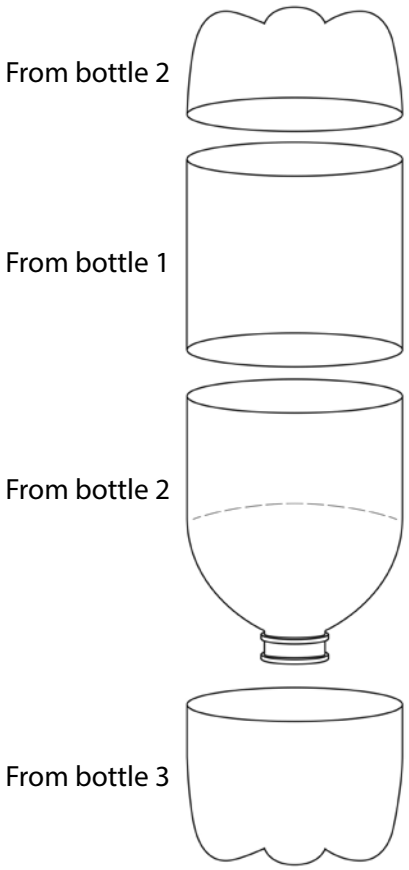


ILLUSTRATION: LES FORTENBERRY

Filling Your Compost Tower

1. Using a small tub, mix roughly equal amounts of bulking agent (soaked in water is best, with excess water drained off) and food scraps. A variety of materials will work, but in general, you want a bulking agent to provide air flow plus some vegetable scraps to provide food for microbes.

2. Once you have roughly equal amounts of bulking agent and food scraps, fill your tower. You want air to be able to diffuse through the open spaces in the compost, so make sure to keep your mix light and fluffy, and do not pack it down. Add a few earthworms to each tower.
3. Put the top piece of the soda bottle on and seal it in place with tape.
4. Each time you collect data, you will need to remove the top and insert the thermometer well into the compost.
5. Since the tower composters are much smaller than the typical compost pile, they will work best if they are wrapped in something to insulate them so they retain the heat that is generated during decomposition.
6. Record the daily progress of your compost by taking temperature readings and observing how the material looks. Can you think of ways to design your own experiment using your compost tower? Using temperature charts and observations, you can compare variables such as the types of compostable materials, moisture levels, amounts of air flow, and insulation systems. Although your composted materials may not look as finished as the compost from larger piles, you will find that the volume will shrink by 1/2 or 2/3 and that the original materials are no longer recognizable.
7. Brainstorm with your students about what they think is an optimal mix for a good compost.
   - Air: the biological activity of fungi, bacteria, small insects, and other organisms results in decomposition. Most biological processes require adequate amounts of oxygen.
   - Biodegradable Substance: capable of being decomposed by bacteria or other living organisms.
   - Water: necessary for normal functioning of life. Too much water in a compost pile may result in a soggy and slow decomposition process by reducing needed oxygen.
   - Nitrogen: many of the organisms responsible for decomposition need nitrogen. Nitrogen is necessary for rapid and thorough decomposition. Nitrogen is found naturally in organic wastes (higher in "green" materials like grass clippings than in "brown" materials like dry leaves), and in many commercial fertilizers.
   - Worms: they eat the waste, helping to break it down; make droppings, which enrich the soil; tunnel through and aerate the waste, facilitating decomposition; and eventually die and become part of the compost.
   - Soil: contains microorganisms that help decomposition.
   - Organic Wastes: such as leaves, food scraps, and grass clippings. Wastes should be varied, including materials with both carbon and nitrogen. By alternating layers of high-carbon and high-nitrogen materials, you can create good environmental conditions for decomposition to occur.
   - Time: decomposition takes time. To speed up decomposition, aerate (by turning it over) your pile every few days; otherwise, just leave it and wait.
   - Heat: produced by chemical reactions resulting from increased biological activity that occurs during decomposition. Heat helps sanitize compost by killing certain organisms like weed seeds, pathogens, and harmful insect larvae.
   - Mass: in order to generate enough heat for optimal decomposition, the pile must contain at least one cubic meter of organic material. The temperatures generated in a soda bottle compost tower may be different from those generated in a larger pile.

Wrap-up

Q: Where and how is carbon used by living organisms?
A: Animals acquire carbon stored in plant tissue when they eat plants. When animals exhale, they release carbon dioxide gas, a by-product of metabolism, which is used by plants in the process of photosynthesis.

Q: How does decomposition help put nitrogen into the soil?
A: Through decomposition, bacteria and fungi break down nitrogen-containing materials such as animal waste and remains of dead organisms in the ecosystem. Decomposers use a portion of the released nitrogen from proteins and amino acids for their own metabolism. Most of the nitrogen is still in the decaying materials in the form of ammonia or ammonium, and this can be taken up by plants.

Q: Why does the temperature of a compost pile become hot?
A: Given the right mixture of air, water, and nutrients to support the rapid growth of microbes, the temperature of compost will increase. This happens because microbes produce heat through cellular respiration (a chemical reaction) as they work to digest the organic matter.

Q: Why is decomposition important, and why does it happen in nature?
A: Life would end without decomposers. Decomposition releases the elements that are needed for life to exist. One of those elements is carbon, and it is recycled by decomposition. Carbon is the physical basis of all life on Earth. After organisms die, decomposition releases carbon into the soil, air, and water. Living organisms then capture the carbon to build new life.

Q: How is composting like recycling?
A: Composting is the process of decomposing organic materials under controlled conditions. Composting is a form of recycling, in which organic wastes such as food scraps and yard clippings are recycled into a resource that can be used to enrich the soil and support plant growth. Composting accelerates the natural processes of decay by providing optimal conditions for growth of decomposer organisms.

Assessment

Share the data your class collected from the compost tower experiment. Analyze the data you collected. Did you see any patterns like similarities or differences in the physical and chemical properties of your compost materials before and after decomposition? Describe the change in properties that you observed. Does the data show that atoms from the original materials in the tower were rearranged into another substance? Explain why or why not, using this guide: Claim (What do you know?) + Evidence (How do you know that?) + Reasoning (Why does your evidence support your claim?) = Explanation

Options

1. Design an experiment using one of these options below.

Construct a compost tower that:

a) is low in nitrogen
b) lacks moisture
c) has little air circulation
d) is made up of a single ingredient like grass clippings
e) includes items like a paper clip, bottle cap, aluminum foil, a pencil, paper, rubber band, plastic bag, etc.

2. Predict rates of decomposition or lack of decomposition and observe actual changes, if any.
3. Use your data from your original compost tower and compare the results.

Cross-Curricular

Have students create a short story from the perspective of an earthworm. The story should depict the chemical and biological processes that occur during decomposition as part of the storyline.

Resources

- Green Tips for Every Occasion **dnr.mo.gov/env/swmp/greentips.htm**
- Homeowners' Guide to Composting **dnr.mo.gov/env/swmp/composting**
- Worm Composting Bin **dnr.mo.gov/env/swmp/worms**
- Break It Down! The Compost Connection video **dnr.mo.gov/pubs/pub697.pdf**
- EPA Infographic **epa.gov/sites/production/files/2015-09/documents/advncng_smm_infogrphc.pdf**
- School-wide Composting **epa.gov/schools-healthy-buildings/facility-and-efficiency-improvements-concerning-waste-reduction-and**

Activity 3.6 Photosynthesis Model Relay

Estimated Time

(1) 50-minute class period

Learning Standards

MLS: 6-8.PS1.B,1, 6-8.LS1.C
NGSS: MS-PS1-5, MS-LS1-6

Objectives

Students will be able to:

1. Model photosynthesis to show that the number of atoms does not change in a chemical reaction and thus mass is conserved.

Teacher Preparation

In this activity, students will play a relay game that will allow them to model the chemical reaction of photosynthesis. To prepare for the activity, you will need to find a space where the students can run safely. Before students get to class, set up the playing field according to the station map. If you are doing the activity on an area with pavement, you may use chalk to draw and label the stations. Place a container at each station, and fill the containers with the appropriate colored beads for each station according to the station map.

Materials

- Flat glass vase beads (for each team):
  - 6 black (these represent carbon atoms)
  - 18 red (these represent oxygen atoms)
  - 12 yellow (these represent hydrogen atoms)
- 6 paper clips per team
- 1 set of game boards for each team (*Relay 1*, *Relay 2*, and *Sun Game Board*)
- 1 station map
- Chalk
- 3 containers large enough to hold flat glass vase beads

Procedure

1. Divide the students into teams of at least 3–6 students.
2. Hand out one set of game boards to each team.
3. Explain to students that they are going to play a game that models the process of photosynthesis and shows them that the number of atoms does not change in a chemical reaction and thus mass is conserved.

   Q: What is the purpose of photosynthesis?
   A: Photosynthesis produces food for plants.

   Q: How does photosynthesis work?
   A: Plants take water up from the roots, take in carbon dioxide with their leaves, and use the energy from the sun to create a chemical reaction that turns the water and carbon dioxide into molecules of glucose and oxygen.

Q: How many molecules of water and carbon dioxide does a plant need to create one molecule of glucose and six molecules of oxygen?

A: A plant needs six molecules of water and six molecules of carbon dioxide to make one molecule of glucose and six molecules of oxygen.

4. Explain to the teams that for Relay 1, they are going to collect the atoms to make 6 molecules of water and 6 molecules of carbon dioxide. Teams will line up and students will run (one person at a time) to the Roots station to collect one molecule of water (2 yellow beads and 1 red bead), until they have filled their game board with 6 molecules of water. They will then run (one person at a time) to collect 6 molecules of carbon dioxide (2 red beads and 1 black bead). At the end of Relay 1, each team should have a game board filled with 6 molecules of water and 6 molecules of carbon dioxide.

Q: Now that each team has 6 molecules of water and 6 molecules of carbon dioxide, can the teams make one molecule of glucose and 6 molecules of oxygen?

A: No, in order to make glucose and oxygen, both products of photosynthesis, the plant requires energy from the sun.

5. Explain to each team that in order to complete the photosynthesis process they will need to collect energy from the sun. Each team will line up and students will run (one person at a time) to the Sun station and collect one energy token (paper clip) to represent the energy needed to photosynthesize. As each member returns to the team station, they will:
    1. Place the energy token (paper clip) on the *Sun Game Board*.
    2. Take one molecule of water (2 yellow beads and 1 red bead) and take one molecule of carbon dioxide (2 red beads and one black bead) from the *Relay 1 Game Board*.
    3. Gently shake the six beads in cupped hands to mimic breaking of the chemical bonds (the beads in their hands are now individual atoms).
    4. Place each atom in their hands on the corresponding space for each atom on the *Relay 2 Game Board*.
        - Continue play until all of the beads are transferred from the *Relay 1 Game Board* to the *Relay 2 Game Board*.
        - The first team to make one glucose molecule and 6 molecules of oxygen wins the game.

Q: Now that you have used the energy from the sun to photosynthesize, what is the final product of the chemical reaction?

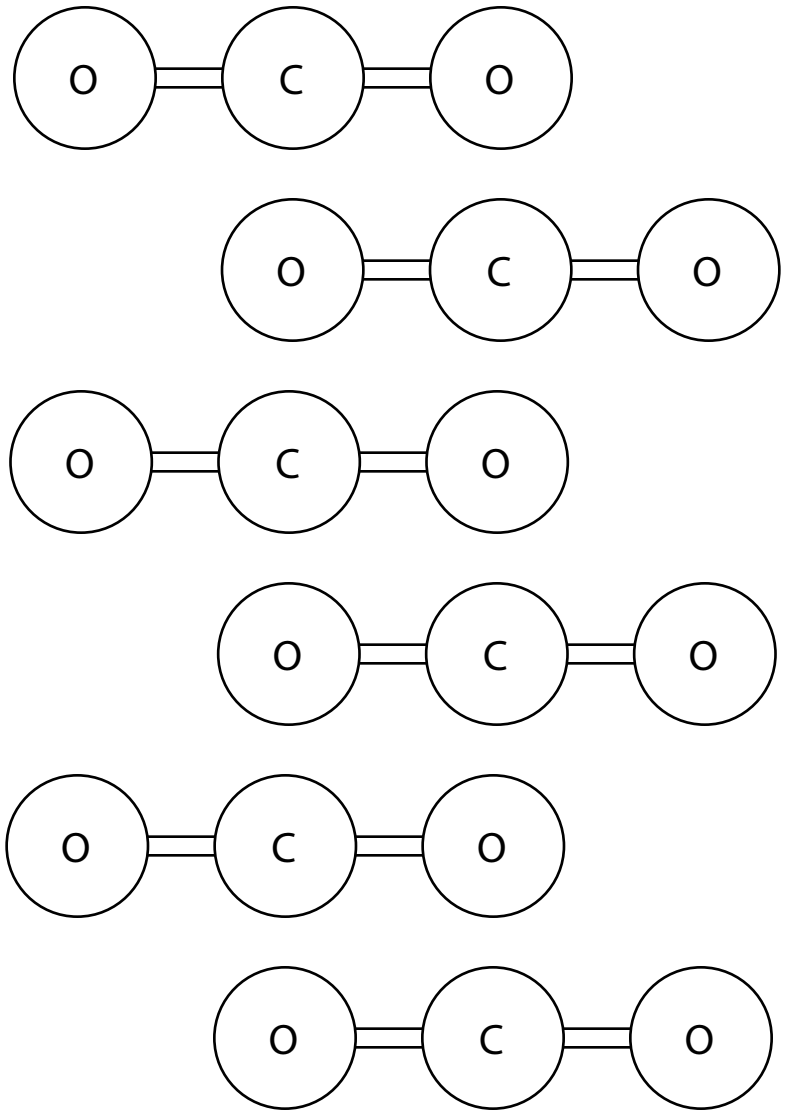
A: One molecule of glucose and 6 molecules of oxygen.

Q: Were there any remaining atoms of carbon, oxygen, or hydrogen after the photosynthesis reaction?

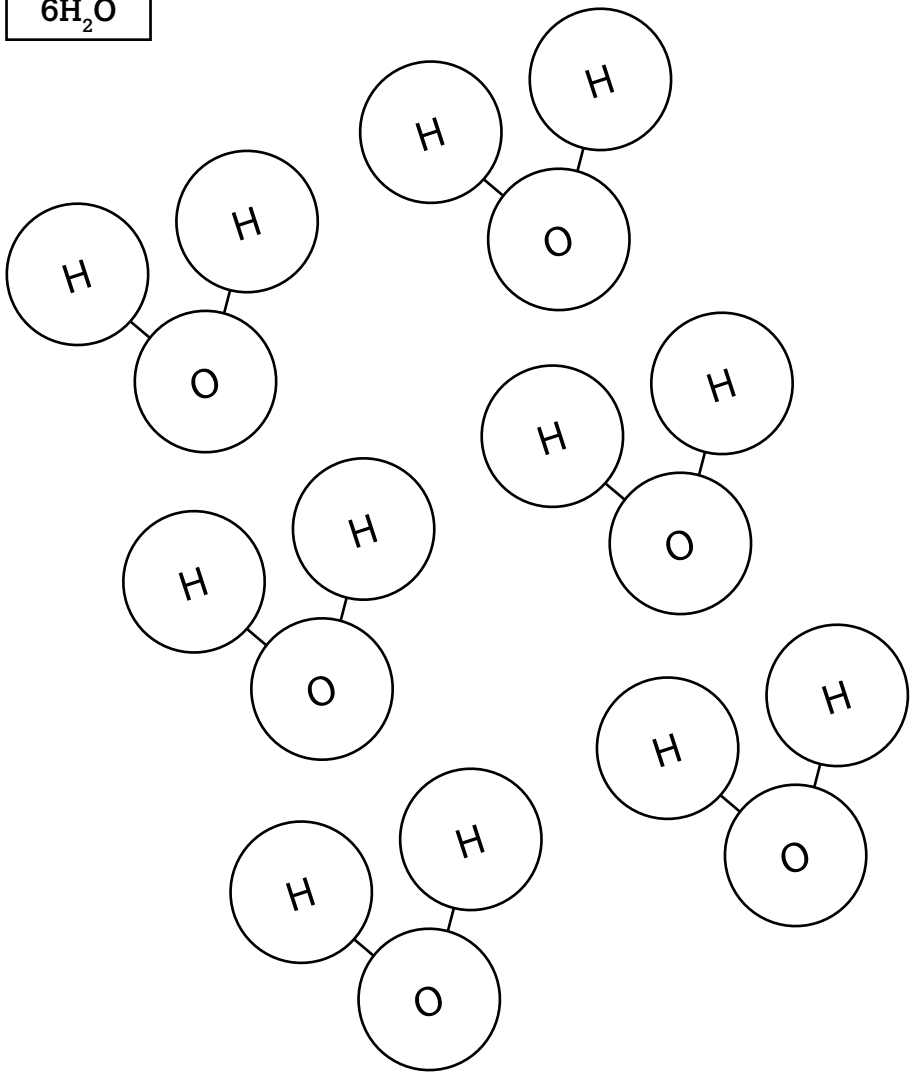
A: No, during the photosynthesis reaction all of the atoms from the molecules of water and carbon dioxide were used to make one molecule of glucose and 6 molecules of oxygen. This shows that the total number of each type of atom is conserved, and thus the mass does not change.

Relay 1 Game Board

$6CO_2$

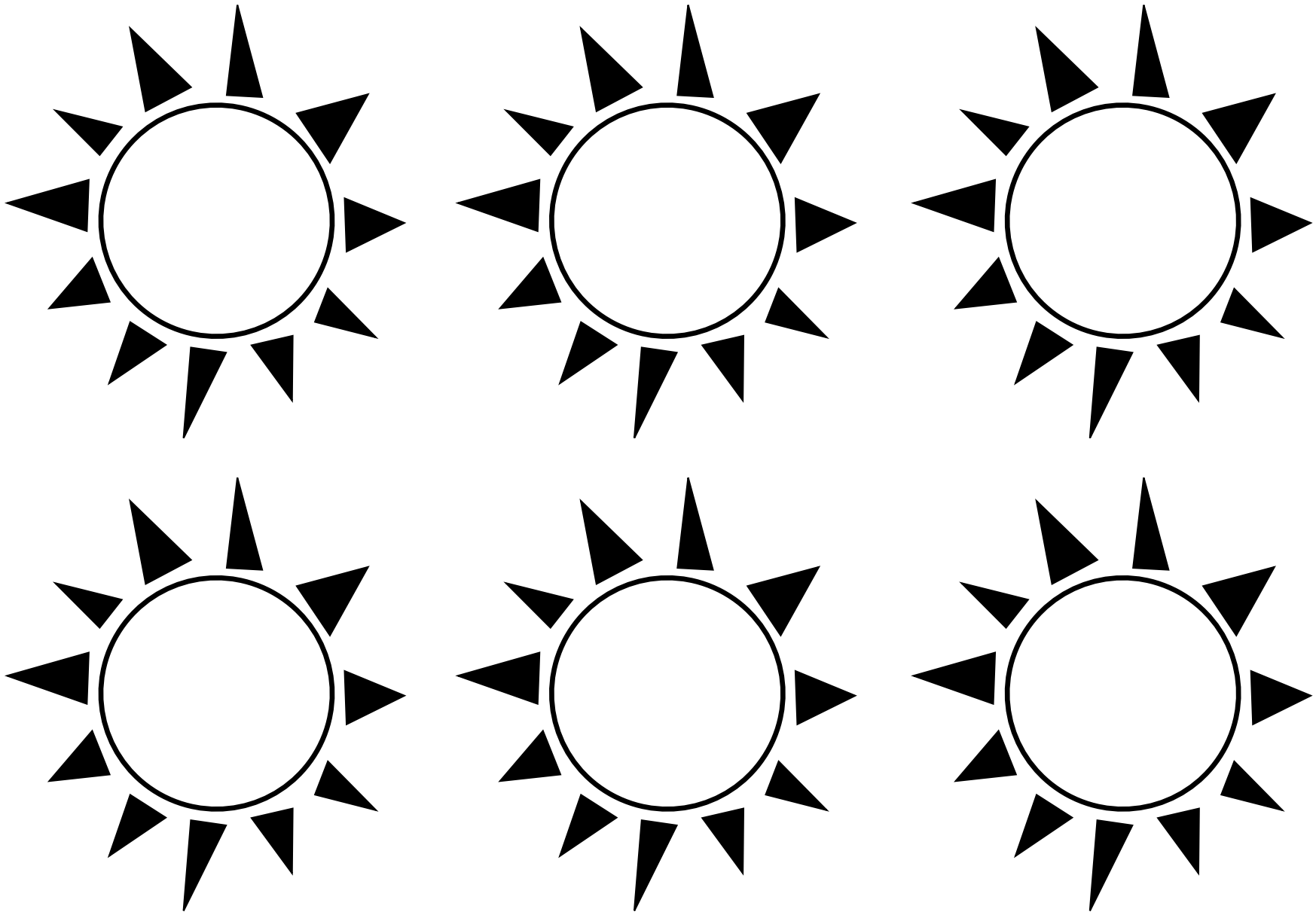


$6H_2O$

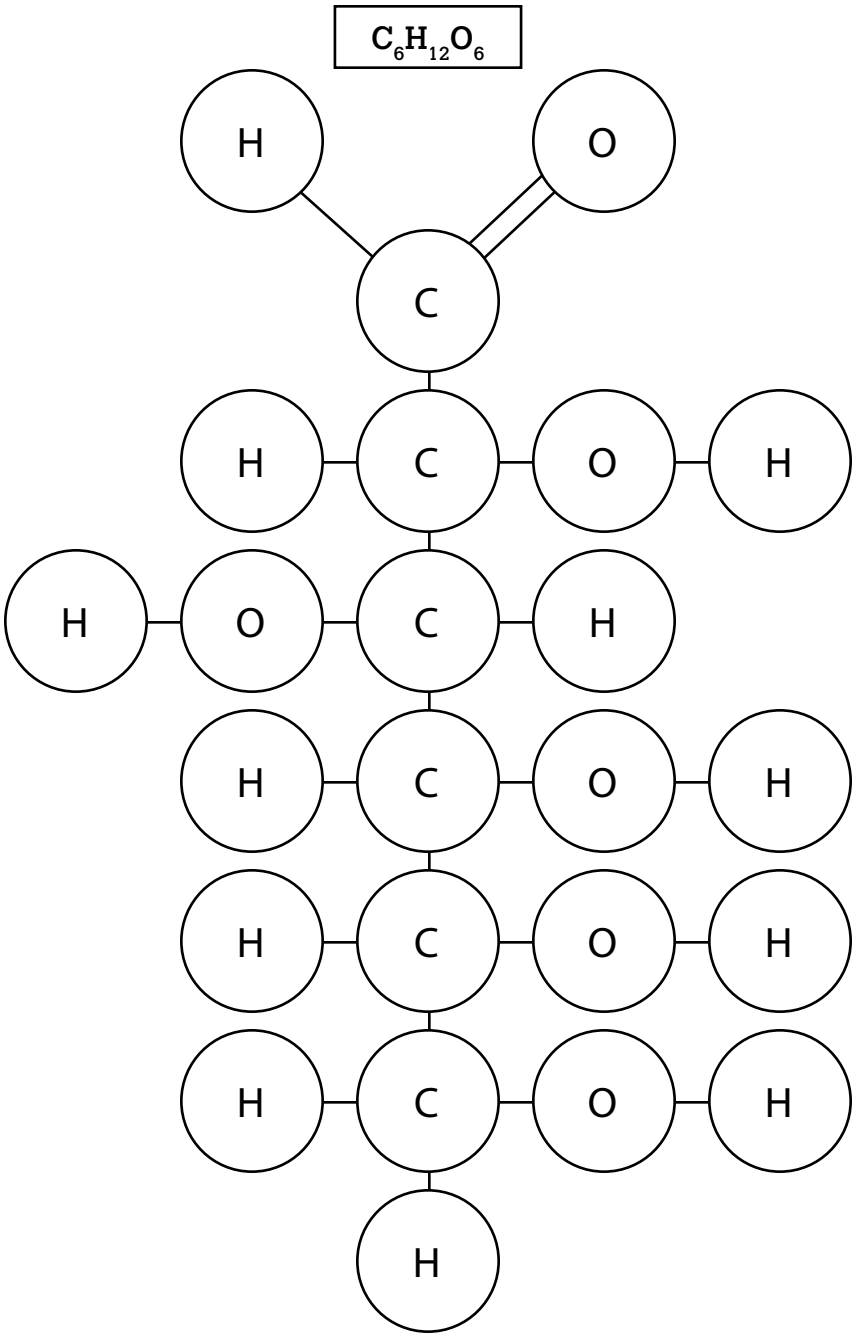


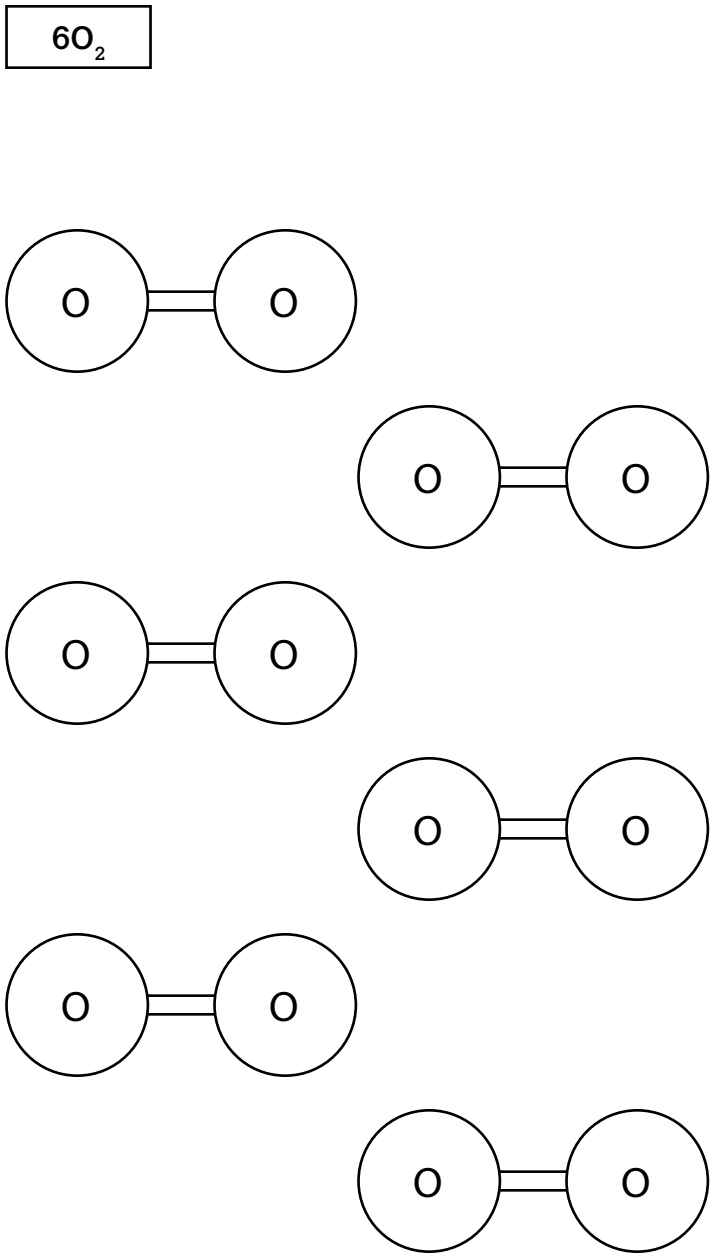
O = Red Bead C = Black Bead H = Yellow Bead

Sun Game Board



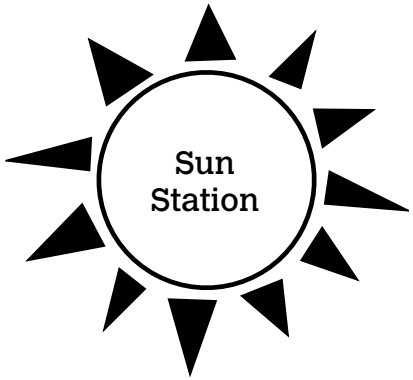
Relay 2 Game Board





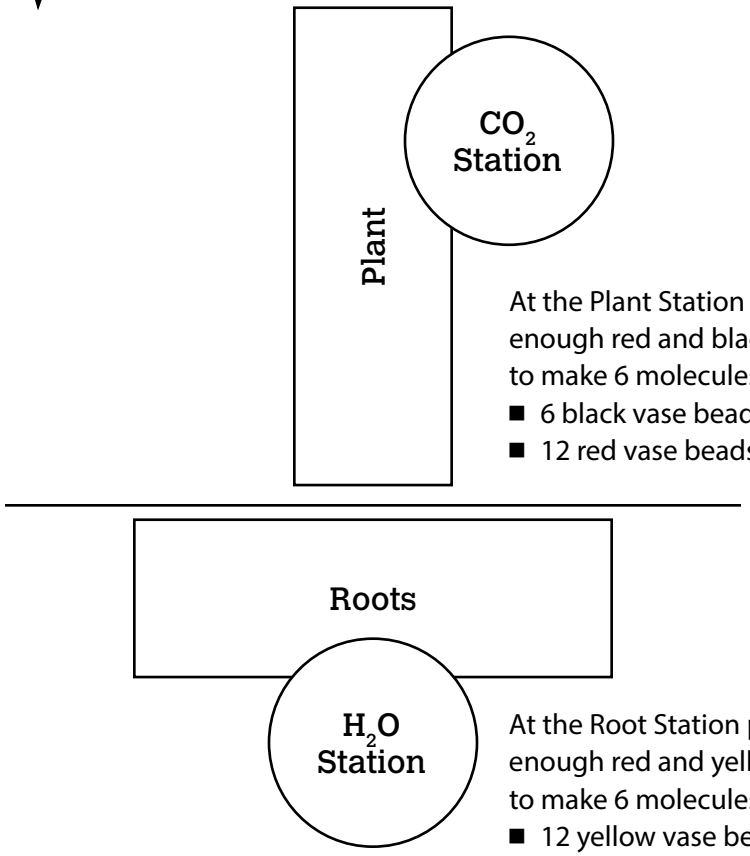
O = Red Bead C = Black Bead H = Yellow Bead

Station Map



At the Sun Station place 1 container filled with enough paper clips for each team to collect 6 tokens of energy.

- 6 paper clips per team



At the Plant Station place 1 container filled with enough red and black vase beads for each team to make 6 molecules of CO_2.

- 6 black vase beads per team
- 12 red vase beads per team

At the Root Station place 1 container filled with enough red and yellow vase beads for each team to make 6 molecules of H_2O.

- 12 yellow vase beads per team
- 6 red vase beads per team

Team 5

Team 4

Team 3

Team 2

Team 1

4 INTERACTIONS

Estimated Time

(5) 50-minute class periods plus fishing

Vocabulary

Adaptation
Carrying capacity
Competition
Competition exclusion principle
Exploitation
Limiting factor
Mutualism
Parasite
Predator
Predator-prey cycle
Resource
Resource partitioning
Warning coloration

Activities

4.1 Interaction Patterns
4.2 Population Limiting Factors
4.3 Identifying Specialized Structures
4.4 Fishing for Specialized Structures
4.5 Mussel Lures

Missouri Learning Standards

6-8.LS1.B.1 Construct an explanation for how characteristic animal behaviors as well as specialized plant structures affect the probability of successful reproduction of animals and plants, respectively.
6-8.LS1.B.2 Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms.
6-8.LS2.A.1 Analyze and interpret data to provide evidence for the effects of resource availability on individual organisms and populations of organisms in an ecosystem.
6-8.LS2.A.2 Construct an explanation that predicts the patterns of interactions among and between the biotic and abiotic factors in a given ecosystem.

Next Generation Science Standards

Performance Expectations

(Science and Engineering Practices underlined)
MS-LS1-4 Engaging in argument from evidence Use argument based on empirical evidence and scientific reasoning to support an explanation for how characteristic animal behaviors and specialized plant structures affect the probability of successful reproduction of animals and plants, respectively.
MS-LS1-5 Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms.
MS-LS2-1 Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.
MS-LS2-2 Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems.

Disciplinary Core Ideas

LS1.B: Growth and Development of Organisms

- Animals engage in characteristic behaviors that increase the odds of reproduction. (MS-LS1-4)
- Plants reproduce in a variety of ways, sometimes depending on animal behavior and specialized features for reproduction. (MS-LS1-4)
- Genetic factors as well as local conditions affect the growth of the adult plant. (MS-LS1-5)

LS2.A: Interdependent Relationships in Ecosystems

- Organisms, and populations of organisms, are dependent on their environmental interactions both with other living things and with nonliving factors. (MS-LS2-1)
- In any ecosystem, organisms and populations with similar requirements for food, water, oxygen, or other resources may compete with each other for limited resources, access to which consequently constrains their growth and reproduction. (MS-LS2-1)
- Growth of organisms and population increases are limited by access to resources. (MS-LS2-1)
- Similarly, predatory interactions may reduce the number of organisms or eliminate whole populations of organisms. Mutually beneficial interactions, in contrast, may become so interdependent that each organism requires the other for survival. Although the species involved in these competitive, predatory, and mutually beneficial interactions vary across ecosystems, the patterns of interactions of organisms with their environments, both living and nonliving, are shared. (MS-LS2-2)

Crosscutting Concepts

Patterns

- Patterns can be used to identify cause-and-effect relationships. (MS-LS2-2)

Cause and Effect

- Phenomena may have more than one cause, and some cause-and-effect relationships in systems can only be described using probability. (MS-LS1-4), (MS-LS1-5)
- Cause-and-effect relationships may be used to predict phenomena in natural or designed systems. (MS-LS2-1)

Activity 4.1 Interaction Patterns

Estimated Time

(1) 50-minute class period

Learning Standards

MLS: 6-8.LS2.A.2
NGSS: MS-LS2-2

Objectives

Students will be able to:

1. Identify examples of competition, exploitation, and mutualism.
2. Role-play three types of interactions — competition, exploitation, and mutualism.
3. Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems.

Teacher Preparation

In this activity, students play a game in which they assume roles as plants and animals and interact with each other. In a given amount of time, students find another organism with which to interact. Students then describe the specific interaction and categorize it as competition, exploitation, or mutualism. Refer to student book pages 26–27.

Multiple rounds are played, giving students opportunities to play different roles and interact in different ways. The object of the game is to role-play in all three categories of interaction. Students will learn that while the species involved may vary, patterns of interactions occur continually and across multiple ecosystems.

This activity uses the set of information cards found on the following pages. Use enough of the cards to facilitate various interaction possibilities. Copy the card pages, cut out the cards, and laminate them. You may wish to have students color the cards before laminating them.

Materials

- Student science notebooks
- Pencils
- Set of *Interaction Patterns Information Cards* (at least one card per student)
- Stopwatch
- Whistle or other signaling device

Procedure

1. Gather students outdoors and explain that they will play a game in which they assume roles as plants and animals. The goal is to find one other organism with which it would normally interact according to the information on their cards. Students should then describe their specific interaction and categorize it according to whether it is an example of competition, exploitation, or mutualism. The first student to role-play in all three categories of interaction wins the game.
2. Distribute one information card to each student, ensuring that enough cards representing producers, consumers, parasites, and pollinators are used in each round of play to facilitate various interaction possibilities.
3. Inform students that they will have 30 seconds to move around to other students, look at other students' cards, and select another organism with which to interact. When students make their decision, each student should stand next to the other student and face the teacher. Interactions are restricted to those that would normally occur according to the information on their cards. Initially, limit interactions to two organisms.
4. Direct students to space themselves out at least an arm's length apart and to hold their cards so other students may see them.

5. Use a whistle or other signal and begin a 30-second timer. Students should make their selections.
6. At the end of 30 seconds, use the signal again. Students should now be standing in pairs.
7. Call on student pairs, asking each student to describe his or her role in the interaction.
8. Ask the pair to categorize their interaction, labeling it as an example of competition, exploitation, or mutualism.
9. If both students have engaged in an appropriate interaction according to the information on their cards, and if they have correctly categorized their interaction, then both students receive credit.
10. Rounds may continue as time allows. Students may keep their original card for each round or may select a different one. As an option, you could remove the restriction of limiting the number of organisms to two. The first student to role-play in all three categories of interaction wins the game.

Wrap-up

1. Have students select a Missouri aquatic ecosystem and write its name in their science notebooks. Students could select from:
   - Pond
   - Lake
   - Stream
   - Big river
   - Marsh
   - Swamp
2. Direct students to describe their chosen ecosystem and list some of its characteristics. For example, a pond is a relatively small body of standing water. It is shallow enough that sunshine can reach the bottom. There is little wave action, and the bottom is usually covered with mud.
3. Have students select a type of interaction (competition, exploitation, or mutualism) that they think might occur in their chosen ecosystem and record this information in their science notebooks.
4. Direct students to conduct research and produce a list of organisms that typically live in their selected aquatic ecosystem. From this list, have students select organisms to play out the roles of the interaction they have chosen.
5. Students should list the names of their selected organisms and describe specialized structures they have that make them suited to their ecosystem and help them play their role in the chosen interaction. Specialized structures should include both physical traits and behaviors that help them survive, interact, and reproduce in their ecosystem.
6. Direct students to explain their predicted interaction, describing in detail the organisms, their specialized structure, and their specific behaviors. Explanations may be verbal or written and may take the form of a description or a story.
7. Have students look for patterns they may see and explain them.
8. Students may explain how the same pattern of interactions may occur in several ecosystems, or how a single organism may participate in several interactions.

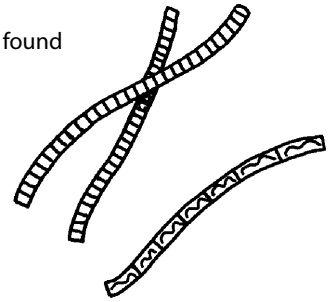
Activity 4.1
Interaction Patterns Information Cards
(Make one-sided copies.)

Algae

Producer: Many varieties found in ponds.

Consumer: Animals that eat aquatic plants.

Habitat: Along shoreline and in open water; must have sunlight to produce food. Along with other plants, algae are the first link in the food chain.



Backswimmer

Foods: This fierce predator eats insects and other invertebrates and sometimes small fish.

Predators: Fish, frogs, birds.

Habitat: Hanging from surface of the water; on or among the plants; occasionally free-swimming.

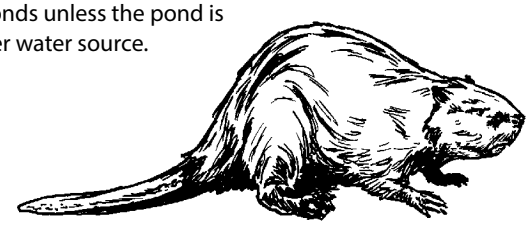


Beaver

Foods: Bark and twigs of shoreline trees. Summer foods include water lilies, pondweeds and cattails.

Predators: Coyotes, bobcats, otters, minks, and humans.

Habitat: Streams, rivers, marshes, small lakes; not normally found in ponds unless the pond is near a larger water source.



Belted Kingfisher

Foods: Mostly fish, some insects, frogs, lizards.

Predators: Raccoons, snakes. Skunks prey on young and eggs.

Habitat: Nests in banks near pond; hovers over water or sits on overhanging branches.

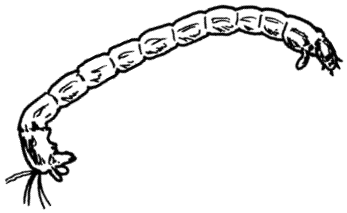


Bloodworm

Foods: Plankton, detritus.

Predators: Large and small fish.

Habitat: Bottom sediments of pond; not really a worm but the larva of a midge (mosquito-like fly).

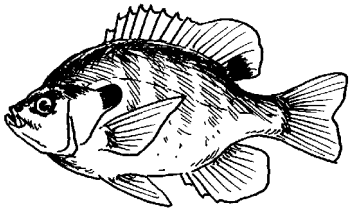


Bluegill

Foods: Mayflies and other insects, crustaceans, small fish, crayfish, snails; algae when animal foods are scarce.

Predators: Bass and other fish, snapping turtles, herons, osprey; adults prized by humans.

Habitat: Open water or along shoreline where food is abundant.



Bullfrog

Foods: Any small animal it can catch and swallow whole, including insects, crayfish, small snakes, minnows, other frogs.

Predators: Any carnivore that can catch and eat it, such as snakes, herons, fish, raccoons, humans.

Habitat: Shores of lakes, ponds, streams.



Caddisfly Larva

Foods: Small crustaceans, insects, worms, diatoms, algae Some species are entirely predacious.

Predators: Fish, diving beetles, giant water bugs.

Habitat: Submerged stems of plants in shallow water; stream bottoms in riffles. They construct a tubular shell from bits of plants or sand particles.

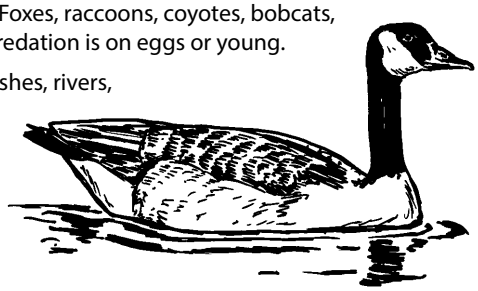


Canada Goose

Foods: Wetland grasses, grains, sedges, roots of water plants.

Predators: Foxes, raccoons, coyotes, bobcats, humans; most predation is on eggs or young.

Habitat: Marshes, rivers, lakes; nests on ground; defends nest vigorously.

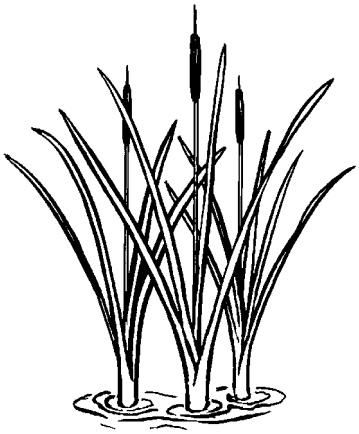


Cattail

Producer: Tall, erect plants with long leaves and usually a green or brown head.

Consumers: Aphids, caterpillars, moths, beetles, birds, small mammals.

Habitat: Rooted along shoreline.

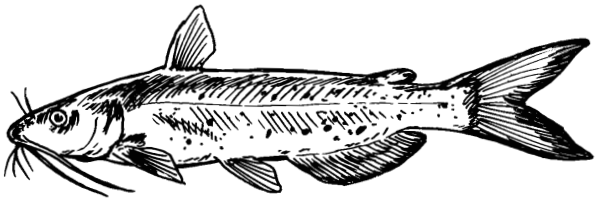


Channel Catfish

Foods: Fish, insects, crayfish, mollusks, plants.

Predators: Young are eaten by other fish. Adults are prized by anglers.

Habitat: Open water or bottom of ponds where they have been stocked.

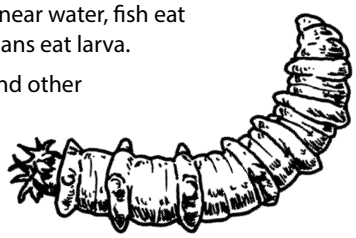


Cranefly Larva

Foods: Larvae can be either predacious on worms or insects, or herbivorous, depending on species. Some adults feed on nectar, but many do not eat at all.

Predators: Birds. If near water, fish eat adults. Fish and crustaceans eat larva.

Habitat: Wet moss and other plants along shoreline.

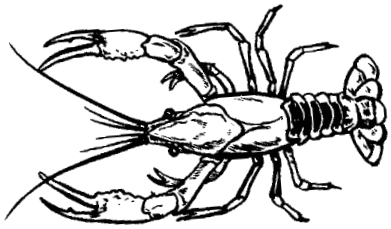


Crayfish

Foods: Both plants and animals. Sometimes crayfish are predators, and sometimes they act as scavengers.

Predators: Raccoons, otters, fish, wading birds, frogs, turtles. Some people consider crayfish a delicacy.

Habitat: Ponds and streams; sometimes in burrows or under logs or plants.

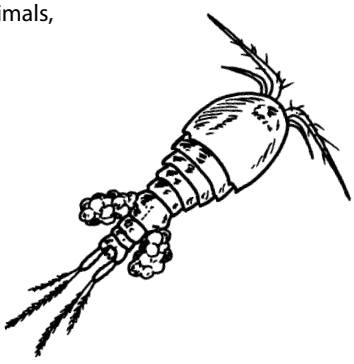


Cyclops

Foods: Microscopic animals, algae, detritus.

Predators: Nearly everything that eats plankton.

Habitat: Open water and shallow water of ponds.

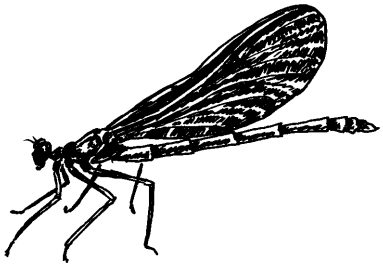


Damselfly Adult

Foods: Mosquitoes, flies, other insects.

Predators: Fish, birds.

Habitat: Plants that grow up and stick out from the water; open air over pond.

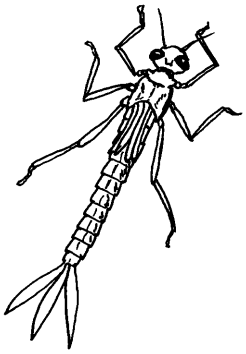


Damselfly Nymph

Foods: Insect larvae, worms, small crustaceans; occasionally small fish and tadpoles.

Predators: Fish, larger insects, crustaceans.

Habitat: Hides among algae and other plants along the shoreline.

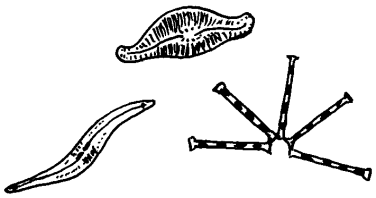


Diatom

Producer: Microscopic algae.

Consumers: Insects, fish, microscopic animals. Diatoms are a major part of the plant-like plankton, which is the basic food source for all consumers.

Habitat: Free-floating or suspended in open water.

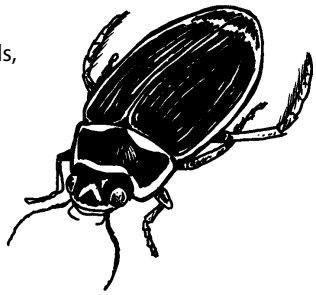


Diving Beetle

Foods: Aquatic macroinvertebrates, or any small animal they can capture. Diving beetles are ferocious predators with large jaws that eat other insects.

Predators: Reptiles, amphibians, fish, wading birds, raccoons, skunks.

Habitat: Usually in weedy shallows along shoreline.

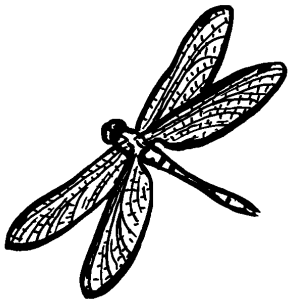


Dragonfly Adult

Foods: Mosquitoes, flies, other insects.

Predators: Birds, fish.

Habitat: Plants that grow up and stick out from the water; open air over pond.

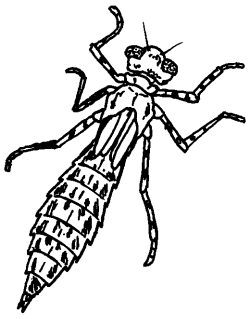


Dragonfly Nymph

Foods: Insect larvae, worms, small crustaceans; occasionally small fish and tadpoles.

Predators: Fish, larger insects, crustaceans.

Habitat: Hides among algae and other plants along the shoreline.



Duckweed

Producer: Small, single-leafed floating plant; rootlets dangle in water.

Consumers: Flatworms, insect larvae, ducks, geese.

Habitat: Free-floating on pond surface.

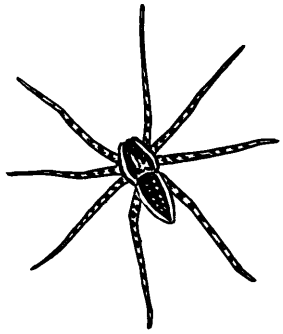


Fishing Spider

Foods: Mostly insects; occasionally small fish and tadpoles.

Predators: Snakes, frogs, some birds.

Habitat: Surface of pond in dense aquatic plants.

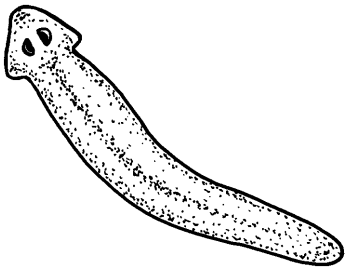


Flatworm (Planarian)

Foods: Small animals; living or dead protozoans or nematodes.

Predators: Worms, insects, crustaceans.

Habitat: Under stones and submerged leaves in dark areas.

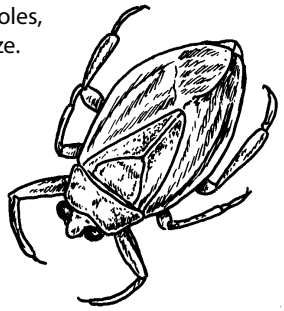


Giant Water Bug

Foods: Fiercely predacious, attacking insects, crustaceans, and even tadpoles, frogs, and fish several times their size.

Predators: Fish, frogs, shorebirds.

Habitat: Hanging from surface of the water; on or among the plants; occasionally free-swimming.

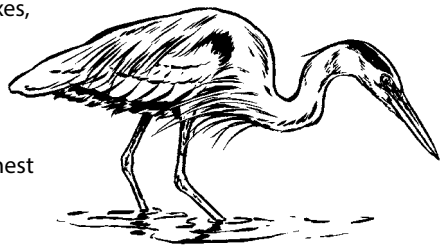


Great Blue Heron

Foods: Mostly small fish, limited numbers of frogs, crayfish, insects, and mice.

Predators: Foxes, coyotes, bobcats; too large for most predators.

Habitat: Marsh, river, lakes; nest in colonies in tops of large, streamside trees.

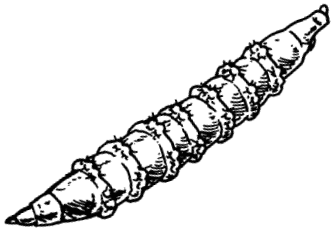


Horsefly Larva

Foods: Worms, snails, other small insects in the water.

Predators: Fish, birds.

Habitat: Among plants and along bottom at edge of pond.

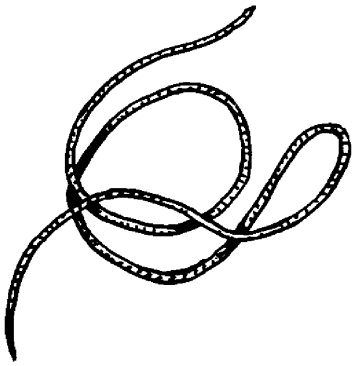


Horsehair Worm

Foods: Immature are parasites, living in various crustaceans, mollusks, or insects. Adults do not eat.

Predators: Fish, giant water bugs.

Habitat: Quiet water.

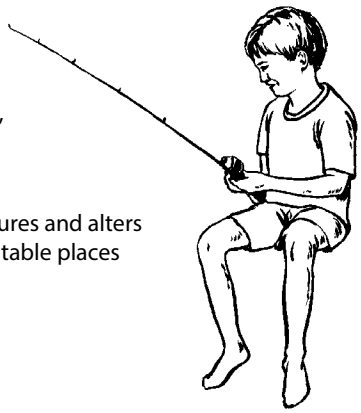


Human

Foods: Bass, bluegill, channel catfish, bullfrog, green frog, crayfish, snapping turtles.

Predators: None.

Habitat: Designs structures and alters environment to provide suitable places to live.

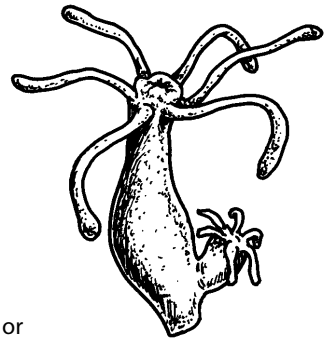


Hydra

Foods: Microscopic animals are trapped in its stinging tentacles. Also, small crustaceans, insects, small clams and fish, seed shrimp, water fleas.

Predators: Carnivorous insects, water beetles, recently hatched trout.

Habitat: Attached to twigs or other plants at the bottom of ponds.

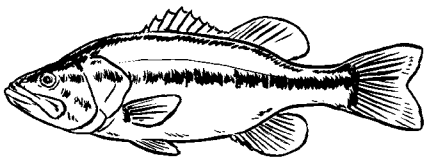


Largemouth Bass

Foods: Adults feed on fish, crayfish, frogs, and large insects. Young feed on daphnia and other small crustaceans.

Predators: Snapping turtles, herons. Small fish are eaten by larger fish. Anglers prize large fish.

Habitat: Open water or along edge where food supply is abundant.

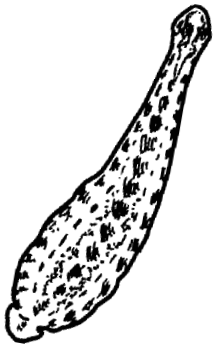


Leech

Foods: Parasite that feeds on the blood of animals. Most attach to fish, turtles, frogs, snails, insect larvae, and other worms.

Predators: Fish.

Habitat: Bottom dwellers.

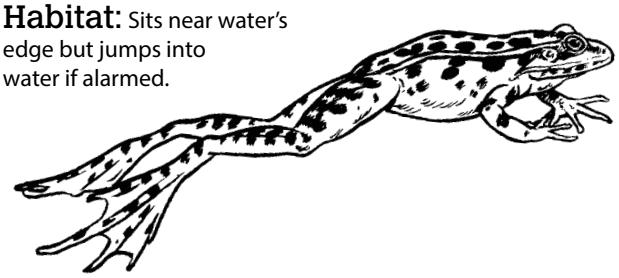


Leopard Frog

Foods: Insects, spiders, other invertebrates.

Predators: Raccoons, snakes.

Habitat: Sits near water's edge but jumps into water if alarmed.



Mallard

Foods: Smartweed, corn, acorns, seeds of many water plants, some aquatic invertebrates.

Predators: Foxes, coyotes, bobcats, minks, humans, raccoons, and skunks.

Habitat: Marsh, lakes, rivers; nests on ground.



Marsh Milkweed

Producer: Moist soil, flowering plant, pollinated by insects.

Consumers: Aphids, caterpillars, butterflies, beetles, and birds.

Habitat: Wetlands and pond edges.



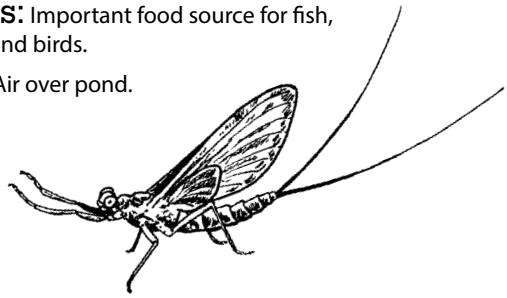
ILLUSTRATION: USDA-NRCS PLANTS DATABASE/USDA NRCS. WETLAND FLORA: FIELD OFFICE ILLUSTRATED GUIDE TO PLANT SPECIES. USDA NATURAL RESOURCES CONSERVATION SERVICE.

Mayfly Adult

Foods: Adults do not eat at all. They live long enough to reproduce, which may only be a few hours.

Predators: Important food source for fish, dragonflies, and birds.

Habitat: Air over pond.



Mayfly Larva

Foods: Small plants, animals, organic debris, diatoms.

Predators: Important food source for fish and other insectivores such as dragonfly larvae and beetles.

Habitat: Various species burrow, live on the bottom, or are free-swimming among aquatic plants.



Mink

Foods: Rabbits, muskrats, other small mammals, birds, fish, crayfish, frogs, crustaceans, insects.

Predators: Humans, dogs, foxes, owls, coyotes, bobcats.

Habitat: These excellent swimmers live in or near wetland habitat including ponds.



Monarch

Foods: Milkweeds and other flowering plants.

Predators: Birds may try to consume monarchs, though they are toxic when eaten.

Habitat: Variety of open habitats, migrates to Mexico for winter.



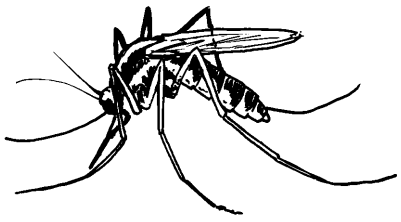
ILLUSTRATION: SABELSKAYA. DREAMSTIME.COM

Mosquito Adult

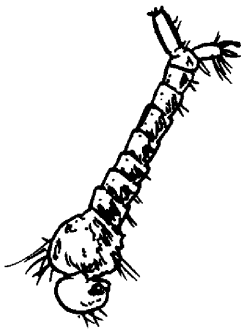
Foods: Females suck mammal blood; males feed on plant juices, if they eat at all.

Predators: Dragonflies, damselflies, other insects, spiders, birds, frogs, fish, bats.

Habitat: Air over water and surrounding areas.



Mosquito Larva



Foods: Tiny plants and animals suspended in the water.

Predators: Fish, other insects.

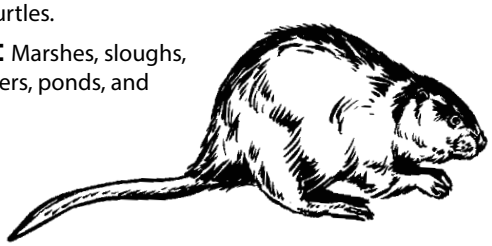
Habitat: Mostly on the water's surface, but dive and hide if threatened.

Muskrat

Foods: Roots, bulbs and foliage of cattails, pondweeds, rushes, and wild rice; will eat fish, frogs, and insects if plants are not available.

Predators: Minks, humans, large hawks, owls, snakes, snapping turtles.

Habitat: Marshes, sloughs, streams, rivers, ponds, and lakes.

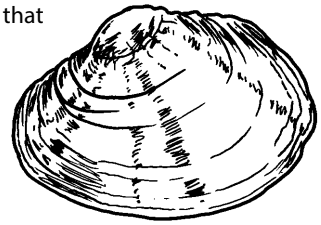


Mussel

Foods: Small bits of organic matter suspended in the water. Because mussels eat small bits of animal matter, they are considered scavengers.

Predators: Fish, muskrats, mink, otters, raccoons; turtles that are able to open the shells or eat the smaller mussels.

Habitat: On the bottom of ponds and streams.

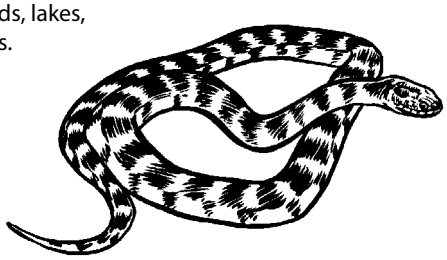


Northern Watersnake

Foods: Crayfish, frogs, tadpoles, small fish, worms, insects.

Predators: Hawks, owls; large game fish eat young snakes.

Habitat: Under rocks or debris near shore of ponds, lakes, streams, and rivers.

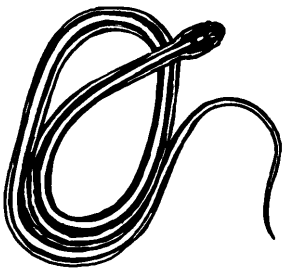


Orange-Striped Ribbonsnake

Foods: Worms, fish, tadpoles, frogs, toads, salamanders, mice, sometimes other small snakes.

Predators: Hawks, owls, snapping turtles, herons. Some fish eat small snakes.

Habitat: Near water, ponds, swamps, marshes, sloughs, streams, and rivers.



Pondweed

Producers: Aquatic seed plant.

Consumers: Birds, muskrats, beaver, deer.

Habitat: Rooted near shoreline.



Raccoon

Foods: Wide variety of small animals, insects, fruits, seeds, garbage, crayfish, frogs, some fish.

Predators: Few as adults. Humans and large carnivores take some young.

Habitat: Forest and forest edge; nocturnal visitor to ponds and streams.

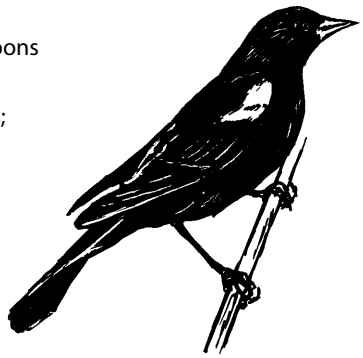


Red-Winged Blackbird

Foods: Insects, seeds.

Predators: Few. Raccoons and snakes will eat eggs.

Habitat: Nest in cattails; migrate south in winter.

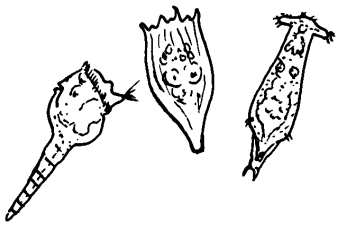


Rotifer

Foods: Microscopic plants and animals.

Predators: Worms, crustaceans.

Habitat: Near shoreline and around aquatic plants; some occur in open water.

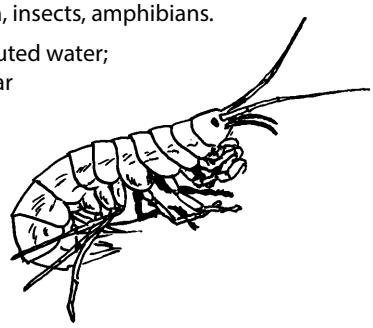


Scud (Amphipod)

Foods: Scavengers on plant and animal debris.

Predators: Birds, fish, insects, amphibians.

Habitat: Clear, unpolluted water; on and among plants; near bottom of pond where they can avoid light.

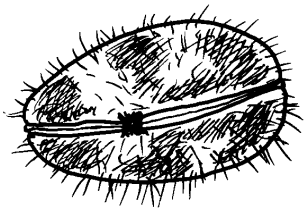


Seed Shrimp (Ostracod)

Foods: Bacteria, fungi, algae.

Predators: Important food source of small fish.

Habitat: On and just above the bottom of ponds.

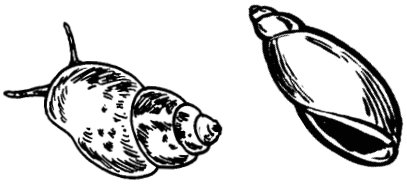


Snail

Foods: Algae, other plants, dead plant and animal material.

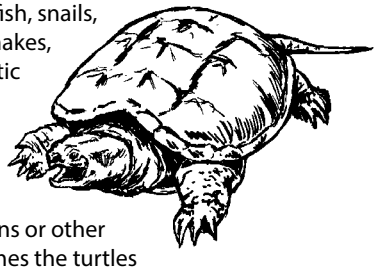
Predators: Many kinds of fish, turtles, some birds.

Habitat: Pond bottom, or on plants and dead material in ponds.



Snapping Turtle

Foods: Insects, crayfish, fish, snails, earthworms, amphibians, snakes, small mammals, birds, aquatic plants.



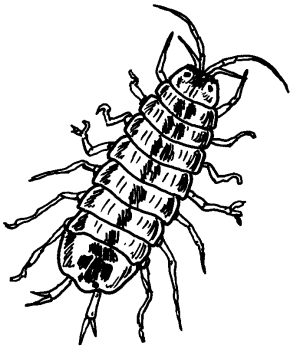
Predators: Few. Humans catch adult turtles for their meat; large fish eat young; snakes or raccoons or other mammals eat eggs; sometimes the turtles are hosts to leeches.

Habitat: Prefer ponds with muddy bottoms, submerged logs and snags, and lots of plants.

Sowbug (Isopod)

Foods: Detritus; decaying plants on the bottom.

Predators: Few; seldom eaten by fish. Some are intermediate hosts for nematodes of fish, birds, and amphibians.



Habitat: Bottom dwellers able to stand acidic water. Some species prefer clear, cold water; all hide beneath rock and other debris.

Springtail

Foods: Decaying plant and animal material; occasionally some living plant material.

Predators: Fish, spiders, frogs, other animals that eat small aquatic invertebrates.



Habitat: Surface of the pond in quiet backwaters. They hibernate but are among the first signs of animal life in the spring.

Stonefly Nymph

Foods: Dead plant material; detritus and fine organic particles and the algae, bacteria, and fungi living on detritus. As they grow larger, they become predators of other invertebrates.



Predators: Fish, other predaceous invertebrates, amphibians.

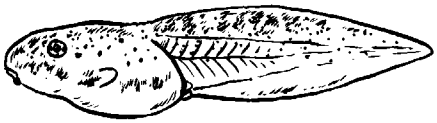
Habitat: Only found in cool, well-oxygenated flowing waters (very sensitive to pollution); crawl about among rocks, gravel, and debris on stream bottom.

Tadpole

Foods: Submerged oozes and scums containing small plants and animals; algae, diatoms, decaying plants.

Predators: Fish, snakes, giant water bugs. Some predacious insects eat small tadpoles.

Habitat: In shallow areas near the water's edge.

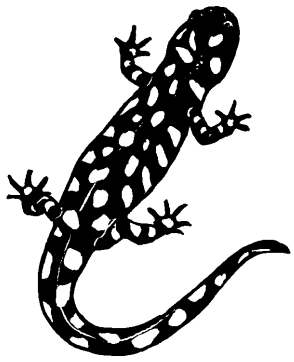


Tiger Salamander

Foods: Earthworms, insects, spiders, slugs, snails.

Predators: Fishes, snakes, snapping turtles, some birds and mammals.

Habitat: In burrows under logs and rocks near water; active only at night.



Water Boatman

Foods: Algae and decaying plants; sometimes dive to feed on decaying animal material on the bottom; sometimes mosquito larvae.

Predators: Fish.

Habitat: Surface of pond, sometimes diving to find food; must cling to something to stay submerged.



Water Flea (Daphnia)

Foods: Filter plankton from the water; algae; organic debris.

Predators: Hydras, insects, fish, some rotifers.

Habitat: Weedy margins of ponds, abundant in all types of water except fast streams and polluted water.

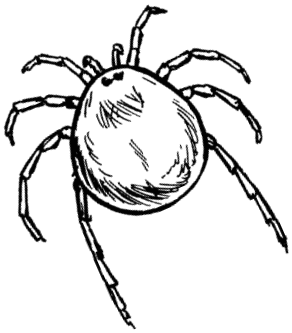


Water Mite

Foods: Insects, worms. Some are parasitic.

Predators: Hydras, insect, fish.

Habitat: Creep on bottom and on plants.

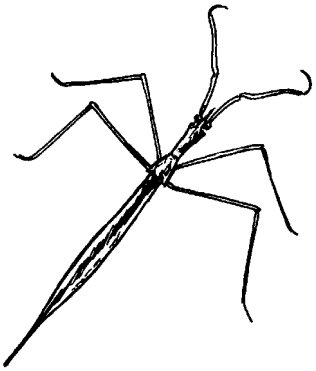


Water Scorpion

Foods: Small insects; seize prey with powerful forelegs similar to praying mantis.

Predators: Some fish, frogs, and birds.

Habitat: Ponds and weedy sections of lakes and streams; hides just under the surface among plants; long breathing tube at rear.

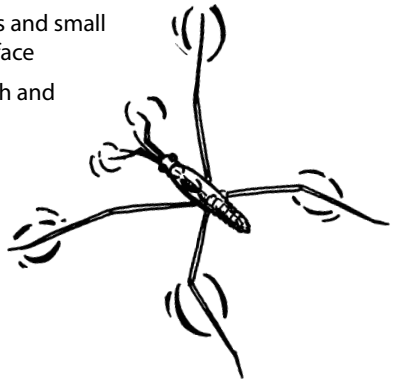


Water Strider

Foods: Prey on insects and small crustaceans near the surface

Predators: Some fish and birds.

Habitat: Surface of water; often seen "skating" over the surface in search of food.

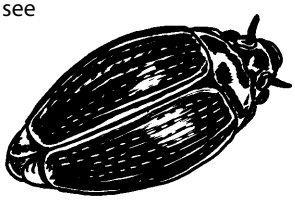


Whirligig Beetle

Foods: Whirl in circles collecting insects and organic debris at the surface.

Predators: Fish, birds, frogs, snakes, and other animals that eat insects.

Habitat: On the surface, often among plants; eyes are divided and can see above and below water at same time.



Activity 4.2 Population Limiting Factors

Estimated Time

(1) 50-minute class period to set up
2 to 3 weeks of observation and data collection

Learning Standards

MLS: 6-8.LS1.B.1, 6-8.LS1.B.2
NGSS: MS-LS1-4, MS-LS1-5

Objectives

Students will be able to:

1. Conduct an experiment on population growth.
2. Collect and plot data on a graph.
3. Identify and describe evidence necessary for constructing explanations.
4. Recognize patterns in data and make inferences about population change.
5. Construct a scientific explanation based on evidence for how environmental factors influence growth of organisms.

Teacher Preparation

For this activity, you will need duckweed, a common and prolific aquatic plant. Duckweed may be collected by you or your students, or it may be purchased from a biological supply company.

You will also need a bucket of pond water. Students will carefully place 3 or 4 individual plants into a paper cup of pond water and then observe them for 2–3 weeks. You may wish to have a specimen or photos of duckweed available to help students identify the plant.

Note: Be sure to properly dispose of the plants used in this investigation by placing them in a closed garbage bag and depositing the bag in a dumpster. To prevent the spread of an invasive species of plant, do not dump the plants in or near any water source.

Materials

- Student science notebooks
- Pencils
- 10 oz. paper cup (one per group)
- 2–3 healthy duckweed plants for each group
- Forceps
- Light source (window or fluorescent light)
- Graph paper
- Graduated cylinder/beaker
- Simple magnifiers
- Metric ruler

Procedure

1. Brainstorm with students about what they think would happen to a population of plants or animals if it were allowed to grow without predators or competition of any kind. Record the answers.
2. Explain to students that they are going to conduct an experiment over the next 2–3 weeks to explore this question. Tell them they will be growing duckweed, an aquatic plant, in an environment without any predators or competition from other species. After the experiment, students will construct an argument supported by empirical evidence to claim that changes to physical components of an ecosystem affect populations.
3. Compare and contrast the growth of duckweed with the growth of plants that may be more familiar to students (like house plants.) Discuss how most plants reproduce. (They grow flowers, pollinate, and produce seeds; then the seeds become new plants, usually over the course of a year.) Show them the thallus (body of duckweed plant) and the roots.
4. Explain to students that duckweed is commonly found floating on top of the water in ponds and lakes. Sometimes it looks like bright green scum on the surface of the water. If you look closer, you will see that the scum is actually made up of tiny individual plants. The plants can reproduce by seeds but seldom do. More commonly, they reproduce asexually by producing a new plant that grows off the old one. When the new plant grows its own roots, it breaks off from the old plant. To determine the growth of a population of duckweed, count the number of thalli that appear over a period of time.
5. Divide the class into groups of 3–5, depending on the amount of materials you have available. Direct each group to measure 250 mL of pond water into a small paper cup. Use forceps (an inoculation loop or wooden toothpick works well, too) to carefully transfer the duckweed plants into the cups containing pond water. Also, have each student take out a few plants to observe. Have the students use magnifiers to look at the duckweed plants and sketch them in their science notebooks. Tell students to label the parts of the duckweed. Direct students to write their names on their container and place the container under a light source.
6. Over the next few weeks, have students count the number of plants they observe in their containers and record their observations in their notebooks. Instruct students to make a T-shaped data table in their science notebooks to record the day (Day 1, Day 2, etc.) and the number of plants in the container.
7. Have students plot their data on a graph, with the **x** axis (independent variable) representing time and the **y** axis (dependent variable) representing the number of plants. This type of graph is called a logistics population growth graph.
8. Explain to the students that the growth of populations may start out by growing exponentially, but abiotic and biotic factors limit and slow the growth of most organisms. Ask students to use their graphs to answer the following questions in their science notebooks.
    1. Describe what happens to the population of duckweed over time. Do you see a pattern in the graph? Identify and mark on your graph the three different phases in the population growth.
        - **A.** Lag phase — little growth in population due to small number of individuals in the population.
        - **B.** Exponential phase — rapid population growth because there are not many limiting factors present.
        - **C.** Stable phase — growth slows due to competition for resources like food or water or due to other biotic factors like predation. The population growth levels out.
    2. Which region of the graph represents the fastest population growth? The slowest?
    3. Are there regions on the graph that represent no population growth at all? Where are they located?
    4. Which part of the graph represents the smallest population? The largest?
    5. What can you conclude from your graph?
    6. What factors seem to be limiting or encouraging growth?
    7. What happens to a population of plants when it is allowed to grow in the absence of any predators or competition of any kind?

Q: Does the data show the stable phase always occurring after the exponential phase?
A: Answers may vary.

Q: Which phase of your graph represents the point where growth slows due to competition for resources like food or water or other biotic factors like predation?

A: This is the stable phase. This occurs when competition for resources like food and space cause the growth rate to stop increasing, so the population levels off. This flat part of the upper line on a growth curve represents the carrying capacity.

Q: What do you think populations need in order to be healthy?

A: Much of what populations need depends upon the fact that every population can tolerate only a certain range of environmental conditions. In general, populations need food, nutrients, water, space, and shelter to be healthy.

9. Explain to the students that resources and other factors in the environment that can lower the population growth rates are called limiting factors. When there are not enough resources to support a population, the population growth rate can be lowered. Limiting factors can lower birth rates, increase death rates, or lead to emigration.

Q: What are some limiting factors that could possibly lower the population?

A: Limiting factors can include light, nutrients or minerals, water, oxygen, disease, competition, exploitation, temperature, space, low food supply, drought, floods, herbicides, pollution, and habitat destruction.

Q: What might be some of the limiting factors which made your duckweed population eventually stabilize, and then begin to drop?

A: Answers may vary.

Wrap-up

Have students write an explanatory paragraph describing how environmental factors influence the growth of organisms. Encourage students to revisit Student Book Chapter 4 vocabulary terms and include such terms in their explanation. Possible vocabulary may include *population, limiting factors, population size,* and *carrying capacity*.

Assessment

Using what you know about populations and limiting factors, choose a limiting factor (food, light, space, water) and predict what might happen to a population of organisms when a limiting factor is applied. Construct a scientific explanation based on evidence for how environmental factors influence the growth of organisms within populations. Keep in mind any patterns of change in the three phases you recognized when you plotted your data to a graph in your duckweed experiment. Use this guide to construct a scientific explanation: Claim (What do you know?) + Evidence (How do you know?) + Reasoning (Why does your evidence support your claim?) = Explanation

Option

1. What might happen to a population if an invasive species with no predators were introduced into an ecosystem? If you could graph the data from this scenario, would your graph look like the S-curve graph you made when you studied duckweed (logistics population growth graph)? Research the exponential population growth model and explain the curved line that was created. Which model do you think shows more realistic population growth in the environment, and why?
2. Suppose we have a bacteria colony that starts with one bacterium, and the population of bacteria doubles every day. What function ***P*** can we use to model the bacteria population on day ***t***?

$P(t) = 2^t$

Have students volunteer values of P(t) to help complete the following table.

t	*P(t)*
1	2
2	4
3	8
4	16
5	32

Q: How many days will it take for the bacteria population to reach 8?
A: It will take 3 days because $P(3) = 2^3 = 8$.

Q: How many days will it take for the bacteria population to reach 16?
A: It will take 4 days because $P(4) = 2^4 = 16$

Q: About how many days will it take for the bacteria population to reach 10?
A: Between 3 and 4 days

Cross-Curricular

To further demonstrate limiting factors and their effects on populations, have students create an illustration of a specific ecosystem including drawings of organisms in that ecosystem. On a separate sheet, students will then create a drawing of the same ecosystem, but depicting a limiting factor such as food, light, space, or water. Drawings should reflect population changes and serve as a graphic model demonstrating effects of limiting factors.

Activity 4.3 Identifying Specialized Structures

Estimated Time

(1–2) 50-minute class periods

Learning Standards

MLS: 6-8.LS1.B.1
NGSS: MS-LS1-4

Objectives

Students will be able to:

1. Identify the form and function of species' specialized structures.
2. Identify structures and behaviors that support successful survival and reproduction.
3. Systematically collect and present data.
4. Make claims regarding specialized structures based on evidence.

Materials

- Student science notebooks
- Pencils
- *Activity 4.3 Missouri Fishes Body Type and Specialized Structures Table* (one per group)
- *Introduction to Missouri Fishes* booklet (may be found at **nature.mdc.mo.gov/sites/default/files/downloads/introduction_fish_missouri-02-2011.pdf**) (one per group)
- Large piece of butcher paper for mapping and graphing
- Sticky notes
- Markers

Procedure

1. Divide students into groups of 3–5 and provide each group with copies of the *Missouri Fishes Body Type and Specialized Structures Table* and the *Introduction to Missouri Fishes* booklet.
2. Have students read "Fish have adapted to diverse habitats," on pages 4–5 of *Introduction to Missouri Fishes*.
3. Using the 2 resources, have the student groups choose one species of fish for each body type.
    - On sticky notes, have students draw an outline of the fish, paying special attention to body shape and special features, and include the name of the fish.
    - On a blank page in their science notebooks, have students write down the following for each species:
        - Common and scientific name of the species
        - Body type
        - Specialized structures and their advantages
        - Best-suited habitat. Considerations for this category should include:
            - Water flow (for example, swift or slow)
            - Cover
        - How the species uses its specialized structures to hunt for or acquire food. Considerations for this category should include:
            - Where within the water column does the fish feed?
            - What is the role of the fish in the food chain? Are they predator, prey, or both?

4. Using the large piece of butcher paper, create a table that resembles the *Water Column Sample Table*.
   - Have students place at least one fish on the table for each body type (for example, rover predator, etc.) in the location of where the fish feeds. Have students make claims based on the evidence collected in their science notebooks as to why they placed the fish in that location.
   - Example: The sculpin is a bottom clinger that is adapted to feeding on the bottom in swift currents. On the table, this sticky note would be at the bottom of the table under the swift current section.
5. Create a simple table to record similarities and differences. Discuss the following as a class:
   - Currently, all of these fish are living in the ideal environment for their specific specialized structures. How are these fish similar, and how are they different from each other?
   - What would happen if all fish had the same body type and specialized structures?
   - Move one fish sticky note on the first table from its prime location to a location where it would be difficult for the fish to survive and pose the following questions:
     - Would this fish be able to live in this new environment? If so, what specialized structures would allow it to survive?
     - What specialized structures would make it difficult for the fish to live in this new environment?
     - If this fish species could survive and reproduce in this new environment, would its population hinder the survival of another fish species?

Wrap-up

Have the students write an explanation as to why anatomical similarities and differences are important. Provide writing prompts as desired.

Cross-Curricular

Have students create the 3-D fish models on the following pages. Have students discuss how the specialized structures allow the fish to survive in a prime location.
Note: Additional 3-D fish models may be found on the Teacher Portal at **mdc.mo.gov/teachers**.

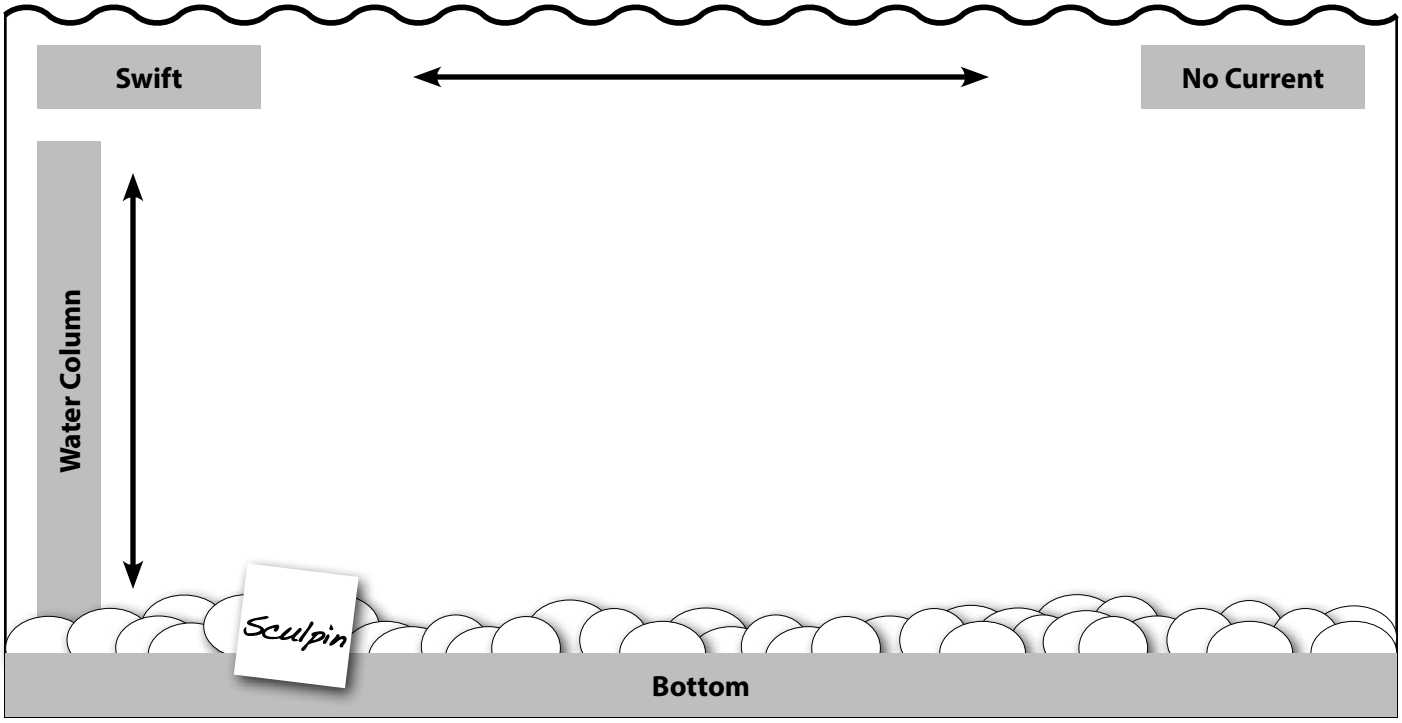
Taking It Home

Have students research the best methods of fishing for two different game fish species. Have students research specific feeding preferences and habitat preferences and explain how knowing those details would affect the choice of lure or bait.

Activity 4.3 Missouri Fishes Body Type and Specialized Structures Table

Body Types	Specialized Structures	Adaptation Advantages	Best Suited Habitat
Rover Predator	Elongated body, fins distributed around the body evenly, pointed head with a large mouth at the tip, forked tail	Allows fish to rove through different habitats. Body shape lends itself to speed.	Still to swift water
Lie-in-wait Predator	Elongated body, fins moved back on the body, pointed head that is flat on top, full mouth of teeth at tip	Elongated body provides thrust for chasing prey. Head and teeth suited for grabbing prey.	Still or slow-moving water with cover for hiding
Deep-bodied Fish	Body is flattened laterally, long dorsal and anal fins, pectoral and pelvic fins are located high on the body	Maneuverability in heavy cover	Still water with heavy cover
Eel-like Fish	Elongated bodies, reduced pelvic and pectoral fins, long anal and dorsal fin	Maneuverability in tight spaces, burrowing in soft substrate	Still to moderately swift water
Bottom Clinger	Flattened heads; large, angled pectoral fins	Enables fish to stay on the bottom within swift water currents	Swift water and riffles
Bottom Rover	Similar body shape to Rover Predator, back is humped, flattened head, enlarged pectoral fins. Mouth shape dependent on feeding style: Omnivores have a terminal mouth, generalists have a subterminal mouth, some bottom feeders (like carp) have ventral mouths with protrusible lips for sucking ooze. Most bottom rovers have barbels for locating food by feel.	Speed to avoid predators, specialized mouth structures for feeding, feel for food versus seeing	Still to swift water
Surface-oriented	Small body, flat head, upturned mouth, dorsal fin is moved back on body.	Adapted to feed at the top of the water column. Most can survive in deoxygenated water by breathing air from surface.	Still water

Water Column Sample Table



3-D Fish Models

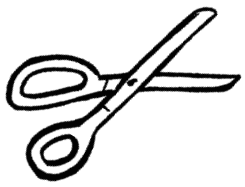
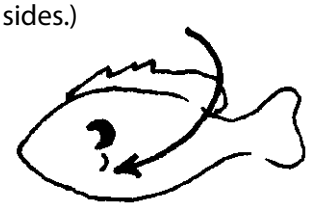
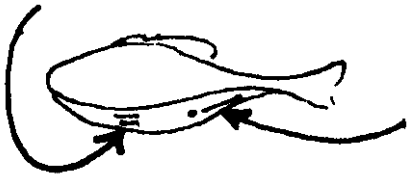
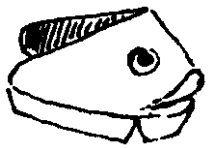
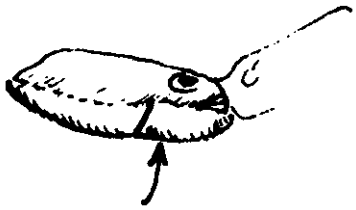
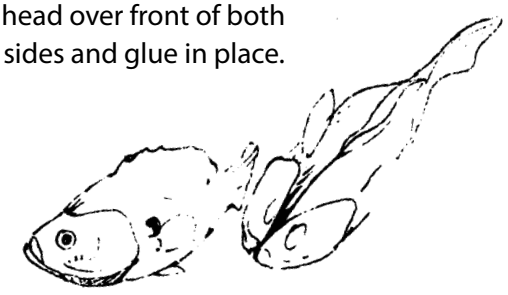
Note: Additional 3-D fish models may be found on the Teacher Portal at **mdc.mo.gov/teachers**.

Longear Sunfish—This fish has a body collard with brilliant blue streaks and orange spots. The iris of the eye is reddish in front of and behind the pupil. Dorsal and anal fins are light orange. Pectoral fins are a dusty grey in color.

Smallmouth Bass—Mouth extends only to the middle of the eye. The body is light green with vertical black blotches or bars.

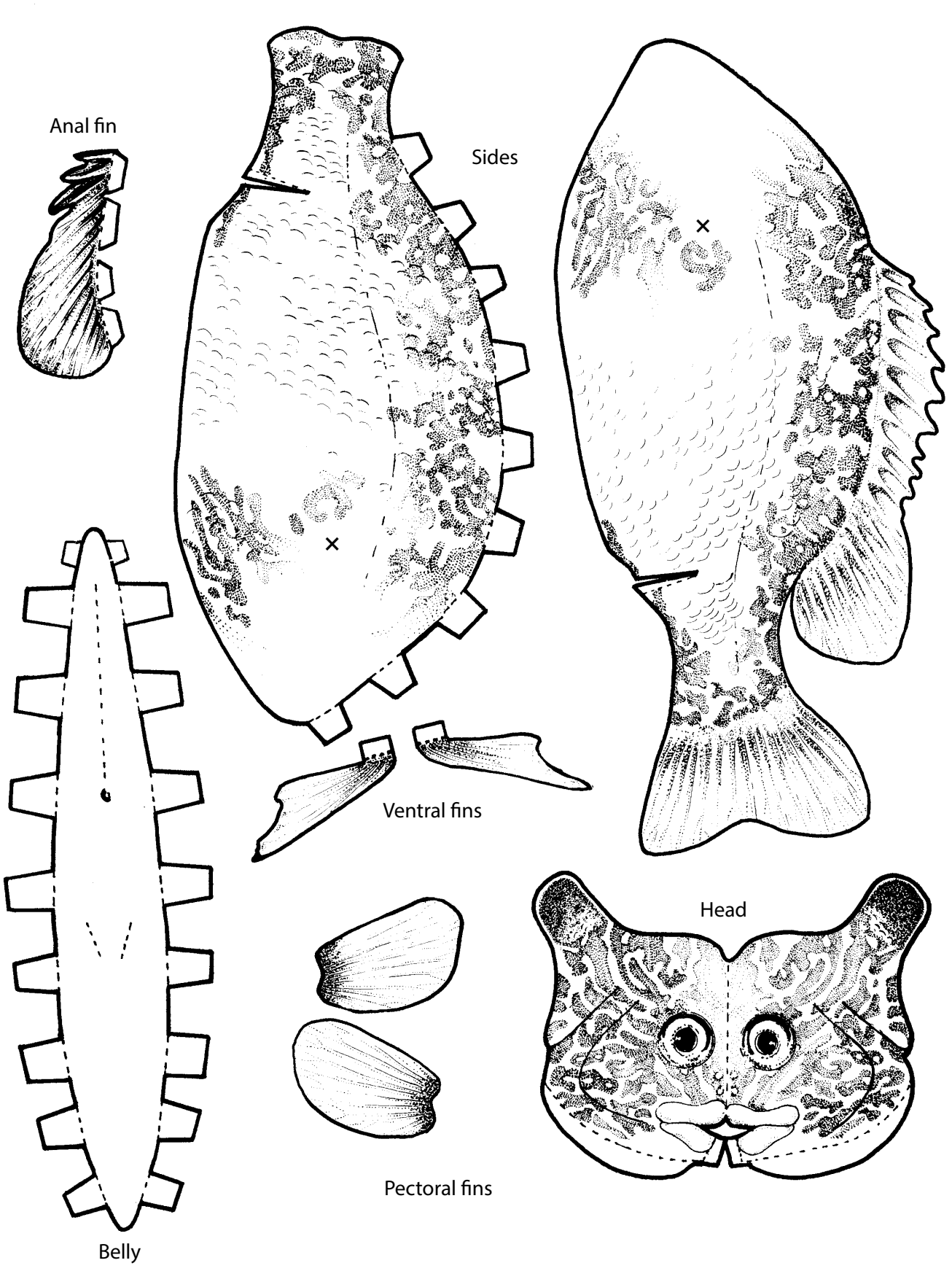
General Directions for Assembly of Fish

- For more stability, copy fish models onto white card stock.
- Do all coloring before cutting and gluing.
- White glue or hot glue work well. If using hot glue, use caution on small parts.
- All tabs are to be folded and then glued to corresponding part to attach.

1. Cut out all parts of fish, making sure to cut around tabs. 	2. Glue both sides of body together by the tabs. 
3. Glue underbelly pieces by the tabs to sides of body. 	4. Glue pectoral fins to the × area near the head on both sides. (Place in front of dashed lines along fish sides.) 
5. Glue ventral fins to short, slanted, dotted lines on underbelly. Then glue anal fins along long dotted line on underbelly. 	6. Fold head tab along dotted lines, trying to maintain curve shape. 
7. Glue head flaps over to dotted lines. 	8. Slide head over front of both body sides and glue in place. 

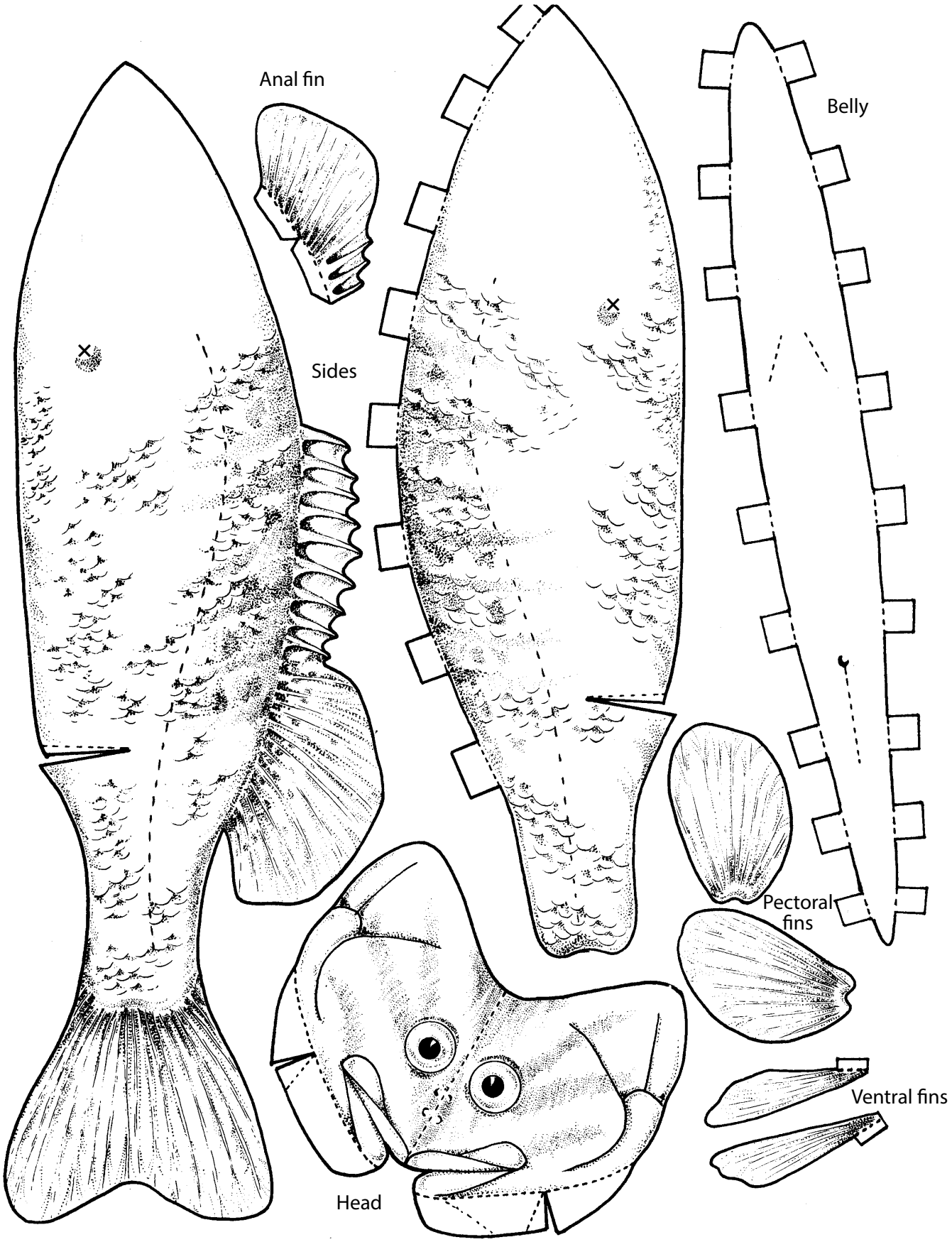
FISH ILLUSTRATIONS: STEPHANIE J. WITTE

Longear Sunfish



ILLUSTRATIONS: STEPHANIE J. WITTE

Smallmouth Bass



ILLUSTRATIONS: STEPHANIE J. WITTE

Activity 4.4 Fishing for Specialized Structures

Estimated Time

(1–2) 50-minute class periods

Learning Standards

MLS: 6-8.LS2.A.2
NGSS: MS-LS2-2

Objectives

Students will be able to:

1. Identify fish caught from local waters during fishing experience.
2. Identify physical characteristics and specialized structures that support successful survival and reproduction.
3. Systematically collect and present data.
4. Draw conclusions regarding adaptations based on evidence.

Teacher Preparation

Fishing while having an understanding of fish structures and habitats is a great way to turn a field trip into a field experience. In this activity students have an opportunity to apply classroom knowledge to a fun recreational activity that will enhance their understanding with hands-on experience. The *Discover Nature — Fishing Instructor Guide*, available through the Teacher Portal, is designed to help educators teach students how to fish — from baiting a hook to properly releasing fish. Contact your Conservation Education Consultant for information regarding trainings and grant funds available to support fishing field experiences.

The previous activity, *4.3 Identifying Specialized Structures*, was designed to give students a basic understanding of adaptations and behaviors as they relate to a fish's habitat. Students will apply the prior knowledge gained from that activity by participating in a hands-on fishing field experience.

Materials

- Student science notebooks
- Pencils
- *Introduction to Missouri Fishes* booklet (may be found at **nature.mdc.mo.gov/sites/default/files/downloads/introduction_fish_missouri-02-2011.pdf**) (one per group)
- *Discover Nature — Fishing Instructor Guide*
- Fishing rods and reels
- Bait and tackle

Procedure

1. Before the fishing field experience, review Lessons 1 and 2 in the *Discover Nature — Fishing Instructor Guide*.
2. Have students create a simple table for collecting data in their science notebooks.

Data Table Example

Species of Fish	Observed Physical Characteristics and Specialized Structures

3. Publications that will help you and your students identify the fish you catch include *Introduction to Missouri Fishes* booklet, *Discover Nature — Fishing Instructor Guide*, *A Summary of Missouri Fishing Regulations*, and *Know Your Catch: Your Guide to Fish Identification*. These publications may be found on the Teacher Portal at **mdc.mo.gov/teachers** or from your local Conservation Department facility.
4. As the students fish, have them record the observed physical characteristics and specialized structures in their tables.
5. When the students return to the classroom, have them compare and contrast the observed characteristics of each fish species by creating Venn diagrams in their science notebooks. Have students write claims of how specific specialized structures help the fish survive.

Wrap-up

Have students construct an explanation based on their observations for the anatomical similarities and differences among the fish species they caught during their field experience. It might help students to refer to *Activity 4.3 Missouri Fishes Body Type and Specialized Structures Table*.

Cross-Curricular

Have students create an advertisement for a specific new type of fishing lure. The advertisement should include the targeted type of game fish as well as an explanation of any specific feeding preferences, habitat preferences, and specialized structures that necessitated the shape, size, and/or function of the lure.

Activity 4.5 Mussel Lures

Estimated Time

(1) 50-minute class period

Learning Standards

MLS: 6-8.LS1.B.1, 6-8.LS2.A.1
NGSS: MS-LS1-4, MS-LS2-1

Objectives

Students will be able to:

1. Explain how animals engage in characteristic behaviors that increase the odds of their reproduction.
2. Explain how anatomical differences among similar animals affect the probability of their successful reproduction.
3. Use evidence to describe the patterns of interaction between freshwater mussels and fish.
4. Describe the negative impacts of pollution, habitat loss, and/or competition by invasive species on aquatic species in Missouri.

Teacher Preparation

Mussels are important species in Missouri's waters and are good indicators of the overall health of aquatic ecosystems. As mussels filter their food from the water, they filter out small particles of organic matter, algae, and bacteria, improving water quality. Mussel filtration rates are high. A single juvenile can filter its own volume of water every second. This helps clean our streams, rivers, and lakes.

Freshwater mussels are bivalves, which means that they have two shells surrounding a soft fleshy body. They live in the sand and gravel bottoms of streams, rivers, and lakes. Mussels require good water quality, stable stream channels, and free-flowing water. They eat algae, other small plants and animals, and bacteria that grow on pieces of plant debris. Mussels are an important food source for fish, some birds, and some small mammals.

Missouri is home to approximately 69 species of native mussels. However, populations of most mussels are in decline due to water quality degradation from pollution, sedimentation, pesticides, nutrient runoff, or alterations to the habitat such as channelization or damming. Competition with non-native invasive species of fish, plants, and mussels also has negative impacts on populations of native mussels, fish, and other aquatic species in Missouri. For example, non-native zebra mussels, quagga mussels, and Asian clams compete with native mussels for food and habitat.

Perhaps the most surprising aspect of native mussels is their relationship with native fish. Mussels need fish to complete their life cycle. Female mussels release their larvae (glochidia) into the gills of many freshwater fish. When glochidia come in contact with the host fish, they clamp onto the gills, where they remain for several days or weeks while they develop. After growing into juvenile mussels, they drop off the fish, causing them little to no harm.

Biologists have discovered that certain species of mussels depend on certain species of fish to serve as hosts for their developing glochidia. If glochidia attach to an unsuitable host, the fish's immunological defenses kill the glochidia. Mussels have specialized structures to lure fish close to ensure that the glochidia become attached to the correctly matching fish species. Mussels attract host fish by waving and offering extensions of their mantles (the soft tissue that lines the inside of the shell) that resemble minnows, worms, leeches, aquatic insects, or crayfish. When the host fish attempts to eat the mantle or fish lure that looks like food, glochidia are released, attaching to the gills, where they remain until they metamorphose into juvenile mussels. If the juveniles drop off onto suitable habitat, they live and grow to start the cycle over again.

In this activity, students play a game outdoors in which they assume roles as mussels and fish. Mussels use their fish lures to attract fish. Mussels are successful if they attract a suitable host fish species in a given amount of time.

Multiple rounds are played, giving students opportunities to play different roles and interact in different ways. Students will learn the role fish play in the life cycle of mussels and will learn how animal physical adaptations and behaviors affect the probability of successful reproduction.

This game uses the set of fish and mussel cards included in this activity. Copy enough of the card pages to ensure that each student has a card and that the ratio of mussels to fish is approximately 50:50. Cut out the cards and laminate them to increase durability.

Materials

- *Activity 4.5 Fish and Mussel Cards* (color version available on the Teacher Portal at **mdc.mo.gov/teachers**)
- Brightly colored note cards or sticky notes
- Stopwatch
- Whistle or other signaling device

Video clip of mussel lure in action: example is the Pink Mucket (the following link requires QuickTime:)
www.biosci.ohio-state.edu/~molluscs/OSUM2/videos/uvs080128-004-1.mov

Short video: Natural Fish Lure/Lampsilis Mussel and Bass — YouTube **www.youtube.com/watch?v=I0YTBj0WHkU**

Procedure

1. View videos of mussels using specialized structures and behavior to attract or lure a host fish.

   Q: What are specialized structures of mussels that help them interact with fish?
   A: Extensions of their mantles (the soft tissue that lines the inside of the shell) that resemble food items for fish like minnows, worms, or crayfish. Some of these specialized structures have coloration and patterns that mimic fish eyes, stripes, crayfish legs, etc.

   Q: What are some behaviors that mussels use to help them interact with fish?
   A: They extend their fish lures and wave or pulsate them to entice fish to attempt to eat them.

2. Round 1 (Don't use cards during the first round)
   a. Gather students outdoors and explain that they will play a game in which they assume roles as mussels and fish. The goal for fish is to find food. The goal for mussels is to attract a particular species of fish and entice it to attempt to eat its fish lure so that glochidia may be released into its gills.
   b. Assign half the class to act like a mussel lure and the other half to act like a fish.
   c. Subdivide the mussels into 3 subgroups (minnows, worms, and crayfish) assigning approximately the same number of students to each mussel subgroup. Explain to the mussels that when the game begins they are to act out their particular lure (minnow, worm, or crayfish). Explain to the fish that they should "swim" around and "bite" any mussel they choose. A "bite" is achieved by the fish standing next to its selected mussel.
   d. Explain to students that the fish will have 15 seconds to "bite" a mussel. Fish may "swim" around to make their selection, but mussels have to stand in one place. A fish may only "bite" a mussel that hasn't been "bitten" and may only "bite" a single mussel in each round of play. Once a fish makes a selection, the fish should stand next to the chosen mussel and face the teacher.
   e. Use a whistle or other signal and begin a 15-second timer. Fish should "swim" around and make their selections.
   f. At the end of 15 seconds, use the signal again. Students should now be standing in pairs (one fish and one mussel.) Have students remain in pairs for the next few steps.
   g. While the students are in pairs, distribute a mussel lure card to each member of the mussel group. Match the lure on the card with the lure the student was assigned in Step C. (minnow, worm, or crayfish).
   h. Randomly distribute a fish card to each member of the fish group.

i. Have a student from each pair read the name of his or her mussel and the fish that "bit" it. Use the Host Fish and Matching Mussels Key to determine if the mussel from each pair was successful. Mussels were successful if they were "bitten" by their particular host fish. Only tell the students if their mussel was successful or not. Do not reveal yet which fish is host for which mussel.

j. Record the number of mussels that were successful in Round 1. Few, if any, mussels will be successful due to the random method of the pairing.

3. Round 2

a. Use the same fish and mussel groups for this round and have students use the same cards they were given after Round 1.

b. Instruct the students who have mussel lure cards to act out their specific lure (minnow, worm, or crayfish.)

c. Instruct the students who have fish cards to read what type of mussel lure they may be fooled by so they will be more likely to find and "bite" the matching mussel.

d. As in Round 1, use a signal and 15-second timer to allow the fish to make their selections.

e. Record the number of successful mussels in Round 2.

Q: Were more mussels successful in Round 1 or Round 2?

A: The number of successful mussels should be higher in Round 2 than in Round 1.

Q: Why?

A: Fish focused on finding mussels that offered lures that were most appealing to them and most likely to fool them. This increased the chances that they would "bite" the particular mussel for which the fish served as host.

Q: Explain how anatomical differences (different mussel lures) among similar animals (mussels) affect the probability of their successful reproduction.

A: Certain species of mussels depend on certain species of fish to serve as hosts for their developing glochidia. If glochidia do not attach to fish, they will not develop. If glochidia attach to the wrong fish, the fish's immunological defenses kill them. Mussels have specialized structures to lure fish close to ensure that the glochidia become attached to the correctly matching fish species. This improves the probability of successful reproduction.

4. Round 3

a. Introduce the fact that mussels aren't successful simply because the correct host fish bites their lure. Fish and glochidia have to survive until the glochidia reach their juvenile stage and become self-sufficient.

Q: What are some factors that could have negative impacts on fish and mussels?

A: Pollution, sedimentation, pesticides, nutrient runoff, alterations to the habitat such as channelization or damming, and competition with non-native invasive species.

b. Redivide all students into 3 groups. One group will be mussels, one group will be fish, and one group will be factors that negatively impact mussels and fish.

c. Distribute mussel cards to mussel students, fish cards to fish students, and distribute brightly colored note cards or sticky notes to the negative factor students.

d. Direct the mussels and fish to proceed as they did in Round 2. In Round 3, however, fish and mussels may be tagged by a negative factor that removes the fish or mussel from the game. Negative factors may run and tag fish and mussels. Fish may "swim" and try to evade negative factors, but mussels may not move. Negative factors must display their brightly colored cards to advertise their potential negative impact, and they should apply sticky notes to mussels and fish to indicate they have been tagged and are out of the game.

e. As in Rounds 1 and 2, use a signal and 15-second timer to allow the fish to make their selections and avoid negative factors.

f. Record the number of successful mussels in Round 3. Consider mussels successful if they found their matching fish and neither mussel or fish were tagged by a negative factor. There may be more successful mussels than in Round 1 but fewer than in Round 2.

Wrap-up

1. Discuss which rounds were easiest, hardest, most successful, and least successful for mussels, and why.
2. Have students describe the pattern of interaction between mussels and fish.

Q: How would you describe the type of interaction between mussels and fish?
A: Exploitation: Glochidia may be viewed as temporary parasites of fish, since they gain nourishment from the fish's blood in their gills. Harm to the fish, however, is negligible.

Q: Besides providing a suitable location and blood for glochidia to develop, can you think of any other benefits fish provide to mussel populations?
A: When fish with glochidia swim to other parts of the stream before glochidia detach, they help start mussel populations in new areas, which may be more suitable than the original location.

Host Fish and Matching Mussels Key

Fish	**Mussel**
Logperch	Snuffbox
Green Sunfish	Rainbow
Smallmouth Bass	Broken Ray
Walleye	Black Sandshell
Niangua Darter	Ouachita Kidneyshell
Channel Catfish	Washboard
Largemouth Bass	Yellow Sandshell
White Crappie	Plain Pocketbook

Resources

- **inhs.illinois.edu/collections/mollusk/publications/guide/species/#lampsil**
- **unionid.missouristate.edu**
- **www.biosci.ohio-state.edu/~molluscs/OSUM2/biv.html**
- **www.biosci.ohio-state.edu/~molluscs/OSUM2/papers/odeewatt.pdf**
- **www.fws.gov/FieldNotes/regmap.cfm?arskey=22854**
- **fws.gov/midwest/Endangered/clams/mussels.html**
- **huntfish.mdc.mo.gov/fishing/species**
- **nature.mdc.mo.gov/discover-nature/field-guide/freshwater-mussels**

Logperch *Percina caprodes*

Habitat: Occurs in all sizes of streams; avoids turbid, silty streams; found in sluggish sections of gravel riffles

May be fooled by this mussel lure: Worm



Green Sunfish *Lepomis cyanellus*

Habitat: Open water or along edge where food is abundant

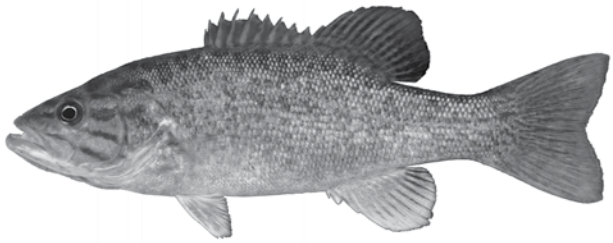
May be fooled by this mussel lure: Crayfish



Smallmouth Bass *Micropterus dolomieu*

Habitat: Small streams with gravel bottom

May be fooled by this mussel lure: Minnow



Walleye *Sander vitreus*

Habitat: Large streams

May be fooled by this mussel lure: Worm



Snuffbox *Epioblasma triquetra*

Habitat: Medium to large rivers in gravel

Lure: Worm



Rainbow *Villosa iris*

Habitat: Cool, clear small to medium streams with gravel bottoms

Lure: Crayfish



Broken Ray *Lampsilis reeveiana*

Habitat: Small streams and headwaters of medium streams in gravel substrate

Lure: Minnow



Black Sandshell *Ligumia recta*

Habitat: Medium to large rivers in sand and gravel

Lure: Worm



FISH PHOTOS: LANCE MERRY
MUSSEL PHOTOS: M. CHRISTOPHER BARNHART

Niangua Darter
Ethesotoma nianguae

Habitat: Rivers with moderate current, found in shallow pools with rocky bottoms

May be fooled by this mussel lure: Minnow



Ouachita Kidneyshell
Ptychobranchus occidentalis

Habitat: Medium-sized rivers in substrate of gravel and mud

Lure: Minnow



Channel Catfish *Ictalurus punctatus*

Habitat: Primarily large rivers with open water

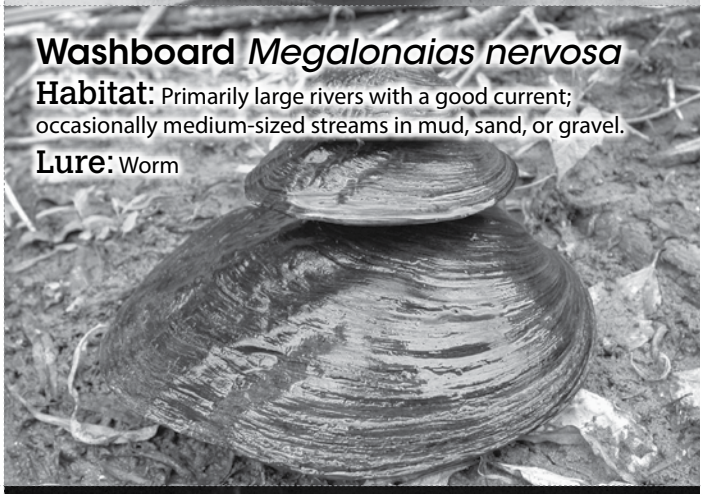
May be fooled by this mussel lure: Worm



Washboard *Megalonaias nervosa*

Habitat: Primarily large rivers with a good current; occasionally medium-sized streams in mud, sand, or gravel.

Lure: Worm



Largemouth Bass
Micropterus salmoides

Habitat: Open, standing water or quiet backwater

May be fooled by this mussel lure: Worm



Yellow Sandshell *Lampsilis teres*

Habitat: Small to large rivers, oxbows, or reservoirs in sand to fine gravel

Lure: Worm



White Crappie *Pomoxis annularis*

Habitat: Deep, open water substrates of fine gravel

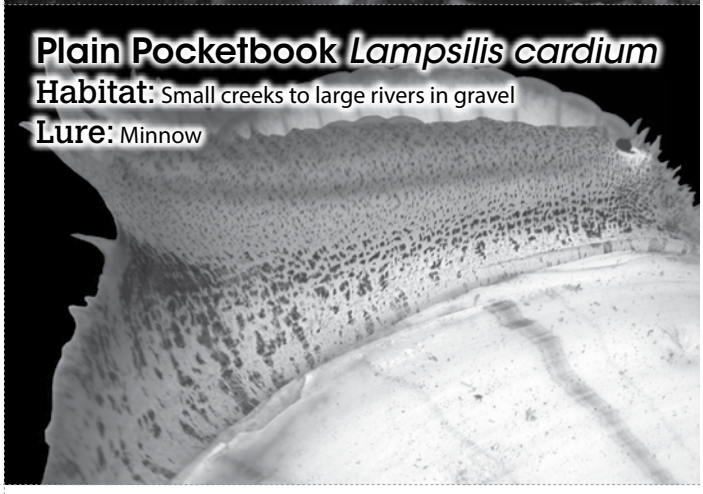
May be fooled by this mussel lure: Minnow



Plain Pocketbook *Lampsilis cardium*

Habitat: Small creeks to large rivers in gravel

Lure: Minnow



FISH PHOTOS: LANCE MERRY
MUSSEL PHOTOS: M. CHRISTOPHER BARNHART

5 BIODIVERSITY

Estimated Time

(2) 50-minute class periods plus aquatic invertebrate sampling

Vocabulary

Bioblitz
Biodiversity
Biological community
Climax community
Disturbance
Early successional community
Ecosystem diversity
Gene
Generalist
Genetic diversity
Habitat fragmentation
Invasive
Keystone species
Pioneer
Relative abundance
Specialist
Species diversity
Species evenness
Species richness
Succession

Activities

5.1 Biodiversity in the Schoolyard
5.2 Aquatic Invertebrate Sampling

Missouri Learning Standards

6-8.LS2.A.1 Analyze and interpret data to provide evidence for the effects of resource availability on individual organisms and populations of organisms in an ecosystem.
6-8.LS2.C.1 Construct an argument supported by empirical evidence that explains how changes to physical or biological components of an ecosystem affect populations.
6-8.LS2.C.2 Evaluate benefits and limitations of differing design solutions for maintaining an ecosystem.

Next Generation Science Standards

Performance Expectations

(Science and Engineering Practices underlined)
MS-LS2-1 Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.
MS-LS2-4 Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.
MS-LS2-5 Engaging in argument from evidence. Evaluate competing design solutions for maintaining biodiversity and ecosystem services.

Disciplinary Core Ideas

LS2.A: Interdependent Relationships in Ecosystems

- Growth of organisms and population increases are limited by access to resources. (MS-LS2-1)

LS2.C: Ecosystem Dynamics, Functioning, and Resilience

- Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations. (MS-LS2-4)
- Biodiversity describes the variety of species found in Earth's terrestrial and oceanic ecosystems. The completeness or integrity of an ecosystem's biodiversity is often used as a measure of its health. (MS-LS2-5)

Crosscutting Concepts

Cause and Effect

- Cause-and-effect relationships may be used to predict phenomena in natural or designed systems. (MS-LS2-1)

Stability and Change

- Small changes in one part of a system might cause large changes in another part. (MS-LS2-4), (MS-LS2-5)

Activity 5.1 Biodiversity in the Schoolyard

Estimated Time

(2) 50-minute class periods

- Period 1: 20 minutes to make observations outdoors, 30 minutes to set up study sites and begin collecting data
- Period 2: 20 minutes to collect data, 30 minutes to analyze and interpret data and construct arguments
- (If you cannot leave study sites set up from one day to the next, you may select the site on day 1 and then mark the site and collect data on day 2. If students need more time to construct arguments, a third day may be added.)

Learning Standards

MLS: 6-8.LS2.A.1
NGSS: MS-LS2-1

Objectives

Students will be able to:

1. Set up and use a study site to collect data to assess biodiversity in the schoolyard.
2. Complete focused observations in a study area and collect data using words, numbers, sketches, and/or labeled diagrams.
3. Compile class data and create graphs, diagrams, or tables.
4. Analyze and interpret data to serve as evidence to support arguments that resource availability and changes in an ecosystem affect populations.
5. Construct and present an argument based on evidence that physical changes in an ecosystem affect organisms.

Teacher Preparation

Walk around the schoolyard or outdoor area to identify good locations where students can set up several small study sites. You will need an area large enough to accommodate groups of 3–5 students, each with their own study site.

You may select several types of landscapes, if available, to study — for example, short lawn grass, taller grass mixed with other plants, old field, woodland, edge of pond or stream, etc. Selecting varying sites will help students make associations between resource availability, populations, and biodiversity.

You may mark study sites with survey flags or tape, or you may allow students to select their own study sites. Decide whether students will set up their study sites using Option 1 or 2:

Option 1. Use a meter stick to measure a square meter on the ground, marking each corner by tapping in a stake. Use string or flagging tape to connect the stakes and establish a square meter study site. Students will collect data about physical and biological components inside their study site.

Option 2. Place a hula-hoop on the ground to designate a study site. If you wish to measure a one square meter area, the hula-hoop circumference should be 354cm.

Materials

- Student science notebooks
- Pencils
- *Activity 5.1 Data Sheets 1, 2, and 3* (included in student science notebook)
- *Activity 5.1 Compiled Class Data* (included in student science notebook)
- Schoolyard maps created in *Activity 2.4 Schoolyard Topography and Mapping* (optional)
- Thermometers (air and soil)
- Compasses
- Meter stick, 4 stakes per group, string or flagging tape, hammer to tap in stakes (Option 1)
- Hula-hoops (one per group of 3–5 students — Option 2)
- Sharpie markers
- Field guides for insects, other invertebrates, and common plants of the area
- Magnifiers (one per group of 3–5 students)
- Cameras, or cell phones or tablets with cameras (optional)

Period 1

Procedure

1. Instruct students to bring their student books, science notebooks, and pencils, and gather students outdoors in the schoolyard. (Schoolyard maps created in *Activity 2.4 Schoolyard Topography and Mapping* are optional.)

   Q: What are three different levels from which we can examine biodiversity?
   A: Species diversity, genetic diversity, and ecosystem diversity

   Q: At what levels can we examine biodiversity in our schoolyard with simple observation techniques?
   A: Species diversity and ecosystem diversity

2. Explain to students that they will make observations about their schoolyard ecosystem from a distance and then will be able to zoom in and make observations from small study sites within the ecosystem.
3. Have students stand or sit and observe the schoolyard landscape. Instruct students to write answers to the following questions in their science notebooks.

   Q: Which ecosystem type(s) can you identify in the schoolyard?
   A: Answers may vary. Students may need to review ecosystem types in Chapter 5 of their student books. Students may also refer to the maps they created of their schoolyard in *Activity 2.4 Schoolyard Topography and Mapping*.

   Q: What physical and biological resources are available to organisms in this/these ecosystem(s)?
   A: Answers may vary. For example, grass and other plants provide food for insects, which provide food for other insects, lizards, and birds. Shrubs and trees provide fruit, nuts, and nesting habitat. Rocks provide shelter, etc.

   Q: What patterns did you observe and what caused them?
   A: Answers may vary.

   Q: Which ecosystem or which parts of an ecosystem in the schoolyard do you predict has the most biodiversity?
   A: Answers may vary. Generally, the more physical and biological resources in an area, the more biodiversity it will have. For example, an area with tall grasses and a variety of plants will have more biodiversity than a short grass lawn with only a few species of grass.

4. Have students watch and listen to the schoolyard landscape, and record observations in their science notebooks using words and/or sketches. Prompt students to listen and watch for insects, birds, and other animals. How many different kinds of species did you hear or see? How many individual animals of each species did you hear or see? Where are the animals in the schoolyard?

5. Divide students into groups of 3–5. Explain to students that they will work in their small groups to establish a study site to assess the biodiversity in their schoolyard. As a group, they will make observations and collect data about the abiotic and biotic factors in their study site. Later, they will use their data as evidence to support an argument that resources affect organisms and populations of organisms.
6. Provide each group with materials needed to set up their study sites. (Meter sticks, etc. for Option 1 or hula-hoops for Option 2.)
7. Assign each group a study site number, and have them label their site with this number and record this number on their data sheets.
8. Direct students to the study sites you have preselected, or have students choose their own areas to set up their sites. If possible, direct students to set up sites in a variety of areas, so they will have varying results and may compare and contrast data.
9. Have students label their study site numbers with a Sharpie marker and identify their ecosystem type.
10. If time allows, have each group start collecting data and completing *Activity 5.1 Data Sheet 1 — Abiotic Factors in Study Site* in their science notebooks. Using a thermometer, have students take and record air and soil temperatures.
11. If option 2 is selected and hula-hoops cannot be left outdoors, have students mark the center of the circle so the hula-hoop can be set in the same place the following day.

Period 2
Procedure

1. Instruct students to determine cardinal directions at the site and note the site's aspect, if applicable.
2. Have students continue collecting data and completing the data sheets.
3. Students should use field guides to identify wildlife and plants. If organisms can't be identified, students should label various organisms as Insect 1, Insect 2, or Plant 1, Plant 2, etc. Students should describe, sketch, or photograph the different species, and they should count and record the number of individuals of each species. It is more important to have an adequate description and sketch of a species than to have it correctly identified if unable to do so.
4. On *Data Sheet 2*, evidence of wildlife might include parts of insects, ant hills, animal droppings, leaves with chew marks, invertebrate exoskeletons, etc. Magnifiers will help with close observation.
5. After all groups have completed all data sheets, have students return to the classroom and compile data from all groups. A large table could be projected or created on a board in class. See *Activity 5.1 Compiled Class Data*.
6. After all groups have entered their data on the compiled table, lead a discussion to prompt students to analyze and interpret the data.

   Q: What are some observations you can make about the compiled data?
   A: Answers may vary.

   Q: Does one type of ecosystem seem to be more diverse than others? If so, what are possible reasons for this? If not, what are possible reasons for this?
   A: Answers may vary.

   Q: Were your predictions correct about which ecosystem in the schoolyard seems to have the most biodiversity? Why or why not?
   A: Answers may vary.

   Q: Is counting the number of species the best measure of biodiversity?
   A: It's only part of the picture. Other factors are relative abundance, genetic diversity, and ecosystem diversity.

Wrap-up

Q: What is the relationship between the amount of resources available and the level of biodiversity?
A: Students should realize that the more physical and biological (abiotic and biotic) resources in an area, the more biodiversity it will have.

Q: Which resources do you think are the most important to biodiversity in your schoolyard?
A: Answers may vary. In their landscape and/or study site observations, students may identify various resources like good soil, variety of ecosystems, multiple species of plants, etc. as important resources to support biodiversity in the schoolyard.

1. In their science notebooks, have students write an argument that changes to physical or biological components of an ecosystem affect populations of organisms. Instruct students to use data, either from their group or compiled from the class, to support the argument.

Extensions

1. Have students create bar graphs that show the total number of species and the total number of individuals of each species observed in their study sites.
2. Have students write a description of their study site and describe its biodiversity. Include a claim with evidence that supports reasons a particular plant or animal was found on the site.
3. Have students calculate relative abundance of species in their study sites. How is relative abundance a factor in species diversity?
4. Have students revisit their study sites at different seasons and compare results. Are results different? Why?

Cross-Curricular

Using information from *Data Sheet 1 — Abiotic Factors in Study Site*, have student groups create 3-D dioramas using cardboard, modeling clay, etc. to include ground cover, any exposed rock and gravel, and other key features, such as percent ground cover, from their study site.

Activity 5.1 Data Sheet 1 — Abiotic Factors in Study Site

Study Site No. _____ Group members _____

Ecosystem Type _____

Air Temperature	
Soil Temperature	
Average Rainfall	
Site includes: (*Check all that apply*) _____ exposed rock or gravel _____ soil _____ pavement _____ ground cover (grass, forbs, shrubs, etc.)	The site has (estimated) _____ percent exposed rock or gravel _____ percent soil _____ percent pavement _____ percent ground cover
Soil Color/Appearance	Soil is _____ sandy _____ clay _____ loam _____ silt
Wind Speed and Direction	
Is the ground sloping, flat, or hilly, etc.? What is the aspect? (If sloping, does the land slope to the N, S, E, or W?)	
Water Source Present (Yes or No)	
If yes, what is the evidence of water present?	
Water Temperature	

Activity 5.1 Data Sheet 2 — Biotic Factors in Study Site — Wildlife

Study Site No. _____ Group members _____

Wildlife Present — Include name or description and the number of individuals found. Descriptions should include size, color, shape, and number of legs.

Insects	**Non-Insect Invertebrates**	**Evidence of Other Wildlife**

Activity 5.1 Data Sheet 3 — Biotic Factors in Study Site — Plants

Study Site No. _____ Group members _____

Plants Present — Include name or description and the number of individuals found. Descriptions should include shape and arrangement of leaves, flowers, and/or fruits.

Grasses/Forbs	**Shrubs**	**Trees**

Activity 5.1 Compiled Class Data

Study Site No.	Ecosystem Type	Total Number of Wildlife Species	Total Number of Plant Species	Total Number of All Species

Activity 5.2 Aquatic Invertebrate Sampling

Estimated Time

May be conducted in a single 50-minute class period in a schoolyard body of water, as an all-day off-site field experience, or in multiple periods. Allow 20 minutes for the optional classroom demonstration version.

Learning Standards

MLS: 6-8.LS2.C.1, 6-8.LS2.C.2
NGSS: MS-LS2-4, MS-LS2-5

Objectives

Students will be able to:

1. Collect aquatic insects and crustaceans and identify them.
2. Classify aquatic invertebrates according to their pollution sensitivity.
3. Examine the species diversity of a body of water by calculating species richness and relative abundance.
4. Collect and analyze data to calculate a water quality rating for a body of water.
5. Collect data to provide evidence for the effects of resource availability on organisms.
6. Construct an argument supported by evidence that changes to the components of an ecosystem affect populations.

Teacher Preparation

This activity will guide your students to discover interesting underwater creatures that usually go unseen — creating awareness of aquatic biodiversity, insect and amphibian life cycles, adaptations, and food webs. Aquatic invertebrate sampling can be a simple investigation of aquatic life in a small pond in the schoolyard, or it can be part of an off-site field experience at a stream or lake in a local park or conservation area.

For the outdoor portion of this activity, you will need a pond, lake, marsh, or stream to conduct sampling. If you don't have a body of water in or near your schoolyard that you can access, contact your Education Consultant, who can recommend good locations for sampling.

Invertebrate sampling is a valuable tool to help assess the biodiversity of aquatic life. When multiple samples are collected, students can calculate species richness and relative abundance. When students understand that aquatic invertebrates can be classified according to their pollution sensitivity, they can understand how aquatic invertebrates can be used as indicators of water quality, especially in streams.

If students are able to compare invertebrate sampling data from different bodies of water or from different sections of a stream (for example, a riffle section versus a pool section) they will be able to make associations between resource availability and organisms and will understand that changes to physical or biological components of an ecosystem affect populations.

Aquatic invertebrate sampling is a great introductory activity for teachers and students who may be interested in forming or joining a Missouri Stream Team and playing a stewardship role for a local body of water.

A wealth of stream and water quality resources are available at the Missouri Stream Team website at **mostreamteam.org**. To view videos that demonstrate aquatic invertebrate sampling techniques, click on the Stream Team Videos tab and scroll down to Biomonitoring Procedures. For resources to help you identify aquatic invertebrates, click on the Stream Team Library tab and then Stream Team Publications to download *Stream Insects and Crustaceans* and the *Key to Macroinvertebrate Life in the River*. A good resource for identifying invertebrates in ponds is *Key to Life in the Pond* (University of Wisconsin — Extension/Wisconsin DNR), which is available from your Education Consultant. These resources are also available to download through the Missouri Department of Conservation's Teacher Portal.

If your students will be sampling more than one body of water in a single day, be sure to follow the *Cleaning and Disinfecting Gear and Equipment Protocol* at the end of this activity to avoid spreading microorganisms like chytrid fungus that are extremely harmful to amphibians.

Invertebrate Sampling — Indoor Classroom Demonstration

Materials

- Student science notebooks
- Pencils
- *Macroinvertebrate Population Samples* cards (one per group)
- *Stream Insects and Crustaceans* (one per group)
- *Activity 5.2 Aquatic Invertebrate Sampling — Water Quality Investigation Data Sheet* (one per group)
- Shallow white plastic pan (optional) (one per group)

Procedure

1. Explain to students that they will soon be modeling the process of collecting aquatic organisms.

   Q: Name some types of organisms that occur in ponds and streams around where we live?
   A: Answers may include snakes, fishes, crayfishes, insects, birds, small mammals, etc.

2. Discuss some invertebrates that live around water and spend at least their larval stage in water. (Dragonflies, damselflies, mayflies, midges, aquatic worms, leeches, snails, etc.) Define "macroinvertebrates." Explain the limited mobility of aquatic macroinvertebrates and what makes them suitable for evaluating water quality. (Water chemistry changes with water flow, so testing water is limited. Macroinvertebrates occupy a pond or stream portion over a long period of time and reproduce in the same area, so the health of their populations may serve as an indication of water quality.) Introduce gilled snails and pond/pouch snails. Explain identification of right-handed and left-handed snails.
3. Present the Missouri Stream Team *Stream Insects and Crustaceans* sheet. Clarify the three categories and give a couple of examples from each group. Explain that some macroinvertebrates are more tolerant of pollution and low oxygen levels than others. Ask students to describe some differences between organisms such as stonefly nymph, water penny, dragonfly nymph, damselfly nymph, and leech.
4. A stream may be simulated at the side of the classroom or in a gymnasium. Lay out a stream using 2 long pieces of rope in a serpentine fashion on the floor. The rope symbolizes the stream bank.
5. Place the *Macroinvertebrate Population Samples* cards throughout the stream. You will want a sample card for each group of students.
6. Briefly explain how in an actual setting, students will use nets and seines to collect organisms. You may wish to show them the equipment so that they can visualize what they will do later.
7. Divide the students into groups and place them along the stream bank. Provide each group with a copy of the *Stream Insects and Crustaceans*, and a copy of the *Aquatic Invertebrate Sampling Water Quality Investigation Data Sheet*.
8. Have students simulate taking a random sample by picking up a *Macroinvertebrate Population Samples* card from their section of the stream. Have students identify the organisms and complete the data sheet.

9. Discuss the results of their findings. Have student groups share their results. You may wish to capture each group's data on a dry erase board or chart paper for comparison.

Q: Which sample indicated the best water quality? Which sample indicated the lowest?
A: Sample 1 has an index of 33 and indicates "excellent" water quality. Sample 6 has an index of 7 and indicates "poor" water quality.

Q: Why are results not the same for each of the 6 samples, and what factors influenced the differences?
A: The types of organisms are different on the sample cards. Even though the number of organisms is the same, different types of organisms have different tolerance ratings.

Q: If this were a real stream, what evidence could you find that might affect macroinvertebrate populations, both positively and negatively?
A: Answers may vary. Negative: erosion, polluting drainage pipe, polluted tributary entering the stream, etc. Positive: clean water tributary entering the stream, increase in stream health after a litter clean-up event, etc.

Q: The water quality index value for Samples 2 and 3 are both 22, however the types of organisms are different. Explain the differences in organisms and the reasons the values are the same.
A: Sample 2 has three "sensitive" types of organisms and Sample 3 has none. However, Sample 3 has a greater number of different organisms. Because it has a greater biodiversity, Sample 3 is apparently as healthy as Sample 2.

Answer Key
Aquatic Invertebrate Sampling Water Quality Investigation Data Sheet for Macroinvertebrate Population Samples

Sample Card No.	1	2	3	4	5	6
Total Index Value	33	22	22	24	14	7
Water Quality Rating	Excellent	Good	Good	Excellent	Fair	Poor

Invertebrate Sampling Techniques for Ponds or Lakes

Materials

(One set for each group of students to be working simultaneously)

- ➤ Student science notebooks
- ➤ Pencils
- ➤ *Activity 5.2 Aquatic Invertebrate Sampling — Water Quality Investigation Data Sheet* (2 per group)
- ➤ *Stream Insects and Crustaceans*
- ➤ *Key to Life in the Pond* and/or *Key to Macroinvertebrate Life in the River*
- ➤ Other invertebrate identification resources
- ➤ D-frame aquatic dip net with mesh of 1/32 inch and a 4-foot pole
- ➤ Clean/new toilet brush
- ➤ Shallow white plastic pan
- ➤ Small magnifier boxes/magnifying glasses
- ➤ White plastic spoons
- ➤ Forceps
- ➤ White ice cube trays
- ➤ Clipboards

Procedure

1. The four main habitat areas of muddy-bottom water bodies are: steep banks with vegetated margins, silty bottom with organic matter, woody debris with organic matter, and sand/rock/gravel. Look for these habitat areas.

Steep banks with vegetated margins

This area is along the bank and the edge of the water body consisting of overhanging bank vegetation, plants living along the shoreline, and submerged root mats. Vegetated margins may be home to a diverse assemblage of dragonfly and damselfly nymphs and other macroinvertebrates. Move the dip net in a bottom-to-surface motion, jabbing at the bank to loosen macroinvertebrates.

Silty bottom with organic matter

Silty substrates with organic matter can be found where the water is slow moving and where there is overhanging vegetation or other sources of organic matter. These silty substrates harbor burrowing invertebrates such as dragonfly nymphs or burrowing mayfly nymphs. Samples are collected by moving the net forward with a jabbing motion to dislodge the first few inches of organic layer, being careful to avoid netting too much mud.

Woody debris with organic matter

Woody debris consists of dead or living trees, roots, limbs, sticks, cypress knees, and other submerged organic matter. It is a very important habitat. The wood helps trap organic particles that serve as a food source for the macroinvertebrates and provides shelter from predators such as fish. To collect organisms from woody debris, hold the net under the section of wood you wish to sample, such as a submerged log. Use the toilet brush to scrub the surface of the log. It also is good to dislodge some of the bark as macroinvertebrates may be hiding underneath. You also can collect sticks and leaf litter and rub roots attached to submerged logs. Be sure to thoroughly examine any small sticks you collect with your net before discarding them. There may be caddisflies, stoneflies, and midges attached to the bark.

Sand/rock/gravel

Large rocks provide the most productive habitat. The bottom can be sampled by moving the net forward with a jabbing motion to dislodge the first few inches of gravel, sand, or rocks. You may want to gently wash the gravel in your screen bottom bucket and then discard the gravel. If you have large rocks (greater than 2 inches in diameter), you should also kick the bottom to dislodge any burrowing invertebrates.

2. Each time you sample, you should sweep the mesh bottom of the D-frame net back and forth through the water (not allowing water to run over the top of the net) to rinse fine silt from the net. This will avoid a large amount of sediment and silt from collecting in the pan and clouding your sample.
3. After collecting your samples, dump the net into a shallow white pan filled with a few inches of water. You should dump your debris into your pan of water after every 3 scoops to avoid clogging the net. Dumping your net periodically also will prevent you from having to sort a great deal of debris all at once. Collect macroinvertebrates from your pan using white plastic spoons, forceps, or fingers, and place like organisms in ice cube trays for identification.
4. Have students sort the macroinvertebrates into lookalike groups as they move them from the pan to ice cube trays. For example, put all macroinvertebrates with legs in one ice cube tray section, and all macroinvertebrates with no legs in another section, etc. This will speed the identification process when students are ready to record results on *Activity 5.2 Aquatic Invertebrate Sampling — Water Quality Investigation Data Sheet*.

Invertebrate Sampling Techniques for Streams

Materials

(One set for each group of students to be working simultaneously)

- Student science notebooks
- Pencils
- *Activity 5.2 Aquatic Invertebrate Sampling — Water Quality Investigation Data Sheet* (2 per group)
- *Stream Insects and Crustaceans*
- *Key to Macroinvertebrate Life in the River*
- Other invertebrate identification resources
- Kick seine (a fine 3 × 3 foot net with 1⁄16 inch mesh and supporting poles on each side)
- Small hand rake
- Small magnifier boxes/magnifying glasses
- White plastic spoons
- Forceps
- White ice cube trays
- Squirt or spray bottle or watering can
- Clipboards

Procedure

1. Select a riffle section of the stream — a shallow, fast-moving area with a depth of 3–12 inches and cobble-sized stones (2–10 inches or larger).
2. Place the kick seine or screen at the downstream edge of the riffle. Be sure that the bottom of the seine or screen fits tightly against the stream bed so that no insects escape under the net. You may want to use rocks to secure the net against the stream bottom. Also, don't allow any water to flow over the top of the net.
3. Sample the stream bed for a distance of 3 feet upstream of the kick seine. Firmly and thoroughly rub your hands over all rock surfaces (top, sides, and bottom) to dislodge any attached macroinvertebrates. Carefully place any large rocks outside of your 3-foot sampling area after you have rubbed off any macroinvertebrates. Stir up the bed with the hand rake until the entire 3-foot-square area has been worked over. All detached macroinvertebrates will be carried into the net. Then for at least 60 seconds, kick the stream bed with a sideways shuffling motion toward the net. Disturb the first few inches of sediment to dislodge burrowing invertebrates.
4. Remove the seine with a forward-scooping motion. Firmly grab the bottom of the net so that your sample does not spill out of the net. The idea is to remove the net without allowing any macroinvertebrates to be washed under or washed from the net surface, or to fall off the net.

5. Place the net on a flat, well-lit area. Using white plastic spoons, forceps, or fingers, pick all the macroinvertebrates from the net and place them in ice cube trays (half full of water). Any macroinvertebrate that moves, even if it looks like a worm, is part of the sample. Look closely, since most insects are only a fraction of an inch long.
6. Aquatic animals will stop moving as the net dries. Occasionally wetting the net using the squirt or spray bottle or watering can may cause the macroinvertebrates to move, making them easier to spot. Watering the net is especially important on hot, dry days.
7. Have students sort the macroinvertebrates into lookalike groups as they move them from the net to ice cube trays. For example, put all macroinvertebrates with legs in one ice cube tray section and all macroinvertebrates with no legs in another section, etc. This will speed the identification process when students are ready to record results on *Activity 5.2 Aquatic Invertebrate Sampling — Water Quality Investigation Data Sheet*.

Identifying Invertebrates

1. Once macroinvertebrates have been collected, have students sort and identify them using the *Stream Insects and Crustaceans, Key to Life in the Pond, Key to Macroinvertebrate Life in the River*, and other invertebrate identification resources.
2. Specimens can be put into magnifier boxes to ease identification. Use characteristics such as body shape, number of legs/tails/antennae, size, color, swimming movement, and gill locations to identify them. When using *Stream Insects and Crustaceans*, remember to read the descriptions for each organism. Also remember that the lines on the card indicate the sizes of the macroinvertebrates, but if students catch a young invertebrate that has just hatched and has not yet reached full size, it may be smaller than indicated on the card.
3. To identify the macroinvertebrates, have students consider body shape, size, and other characteristics (number of legs and tails), because the same family can vary in size and color. Have students consider the following questions to identify an macroinvertebrate:
   - How large is the macroinvertebrate?
   - Is the body long and slender, round, or curved?
   - Does the macroinvertebrate have any tails? How many?
   - Does the macroinvertebrate have any antennae?
   - Does the macroinvertebrate have legs? How many? Where?
   - Is the body smooth and all in one section, or is it segmented (with two or more distinct sections)?
   - Does the macroinvertebrate have any gills (fluffy or platelike appendages)?
   - Where are the gills located? Sides, back, underside, or under its legs?
   - Does it have pinching jaws like a beetle larva?
   - Are any legs or antennae missing because they were broken off in the net?
   - What color is the macroinvertebrate?
   - Does the macroinvertebrate swim underwater or remain on the surface?

Calculating Species Richness and Relative Abundance

1. Have students identify two bodies of water or different parts of the same body of water to compare species diversity.
2. Have students describe these two sample areas in their science notebooks and label them Sample A and Sample B.
3. Have students agree on identical sample methods and sizes for each sample area. For example, three D-frame net scoops for Sample A and three scoops for Sample B, or one kick seine set for Sample A and one set for Sample B.
4. After students have collected samples and identified the macroinvertebrates, have students calculate the species richness by counting the number of species in each sample. Have students record the species richness number for Sample A and for Sample B.
5. Instruct students to list the species in a row across a page in their science notebooks, leaving space beneath the row to record more data. Students should have a species list for Sample A and for Sample B.

6. Instruct students to calculate relative abundance by counting the number of individuals of each species in each sample and recording this number beneath each species name. Have students record the relative abundance numbers for Sample A and for Sample B.

Calculating a Water Quality Rating

Note: Very few macroinvertebrates sensitive to pollution (those listed in the left column of the *Aquatic Invertebrate Sampling — Water Quality Investigation Data Sheet* and those in Group One Taxa of the *Stream Insects and Crustaceans* sheet) will be found in ponds and lakes. However, the water quality data sheet may be used regardless of where sampling takes place. Macroinvertebrates not listed on the data sheet may be included by adding them to the *Tolerant* column.

1. After students have identified the macroinvertebrates, have them record their results on *Activity 5.2 Aquatic Invertebrate Sampling — Water Quality Investigation Data Sheet* (included in student science notebook).
2. Instruct students to calculate and compare water quality ratings for two bodies of water or different parts of the same body of water. These sample areas could be the same as those identified to compare species diversity (Sample A and Sample B).
3. Instruct students to tabulate their results to determine the water quality using the instructions on the survey sheet. Count the number of types of macroinvertebrates (not the number of individuals) in each column and multiply by the index value at the bottom of the column. The rating is based on the diversity and sensitivity of the macroinvertebrates, not the number of individuals found. Add the subtotal for each column and compute the final water quality rating.
4. Have students record the water quality rating for Sample A and for Sample B.
5. Have students return specimens to the water after they have finished.

Wrap-up

Analyzing/Interpreting Data and Constructing Arguments Based on Evidence

1. Have students review the data they collected for two bodies of water or different parts of the same body of water (Samples A and B).

   Q: According to your data on species richness and relative abundance, which sample area has a greater species diversity?
   A: Answers may vary. If different groups of students sampled the same areas, compile class data to determine which area has a greater species diversity.

   Q: According to your data on water quality, which sample area has a higher water quality rating?
   A: Answers may vary. If different groups of students sampled the same areas, compile class data to determine which area has a higher water quality rating.

   Q: Does the sample area with the highest water quality rating also have the greatest species diversity? Why or why not?
   A: Answers may vary. Whether the answer is yes or no, guide students to make associations between resource availability in an area and populations of macroinvertebrates in the same area.

   Q: What are some resources in your sample area that are required by the organisms that live there?
   A: Answers may vary but should include producers, sunlight, prey items, habitat, shelter, space, proper temperature, and (for sensitive macroinvertebrates) clean water with enough dissolved oxygen.

2. Have students write a short paragraph in their science notebooks that explains the relationship between resource availability in an area and populations of macroinvertebrates in the same area. Have students include references to their data to provide evidence for their explanations.

3. Have students construct an argument in their science notebooks that changes to physical or biological components of an ecosystem affect populations in that ecosystem. Students may create and describe scenarios in which ecosystem disruptions affect populations of organisms in that ecosystem. Have students include references to their data to provide evidence for their argument.

Taking It Home

Encourage students, either as a class or with their individual families, to research the existence of a local Stream Team in their community. If there is one, have students discuss the possibility of joining as a class or with their families. If no Stream Team is present, have students discuss the possibility of creating one. A wealth of stream and water quality resources are available from the Missouri Stream Team at **mostreamteam.org**.

Activity 5.2 Aquatic Invertebrate Sampling — Water Quality Investigation Data Sheet

Group _____
(names)

Date _____ Location _____

Invertebrate Occurrence

Sensitive	Somewhat Sensitive	Tolerant
_____ caddisfly larvae	_____ beetle larvae	_____ aquatic worms
_____ dobsonfly larva	_____ clams/mussels	_____ blackfly larvae
_____ mayfly nymphs	_____ crane fly larvae	_____ leeches
_____ gilled snails (right)	_____ crayfish	_____ midge larvae
_____ riffle beetle adults	_____ damselfly nymphs	_____ pouch snails (left)
_____ stonefly nymphs	_____ dragonfly nymphs	_____ other snails (flat)
_____ water penny larvae	_____ scuds	
	_____ sowbugs	
	_____ fishfly larvae	
	_____ alderfly larvae	
	_____ watersnipe flies	
Count the number of types (not number of individuals) _____ × 3 = _____ index value	Count the number of types (not number of individuals) _____ × 2 = _____ index value	Count the number of types (not number of individuals) _____ × 1 = _____ index value
Now add together the three index values from each column for your total index value. Total index value = _____		

Compare this total index value to the following ranges of numbers to determine the water quality of your stream. Good water quality is indicated by a variety of different kinds of organisms and the sensitivity of the organisms, not the number of individual organisms found.

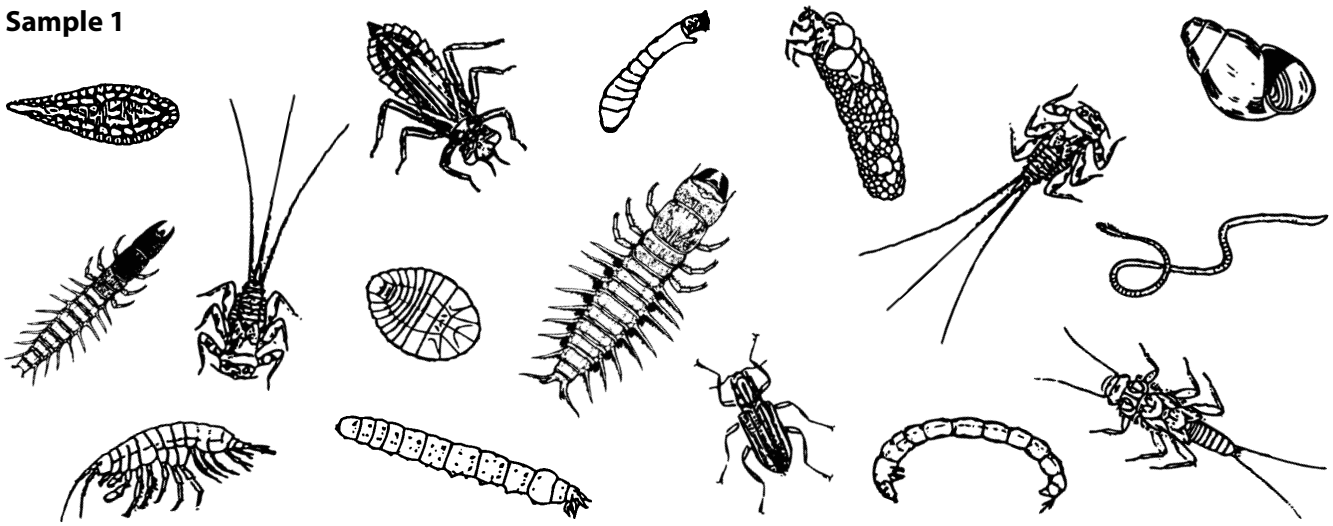
Water Quality Rating

_____ Excellent (>22) _____ Good (17–22) _____ Fair (11–16) _____ Poor (<11)

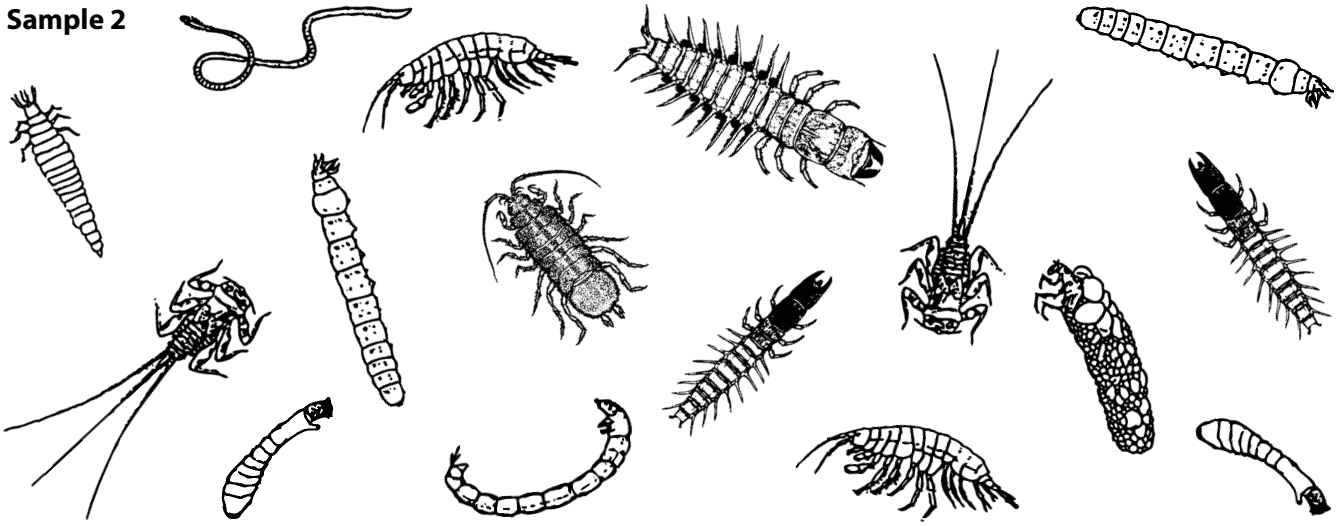
Note: This water quality rating is only valid for gravel bottom streams. Other bodies of water, such as ponds, will have lower index values but not necessarily lower water quality.

Activity 5.2 Invertebrate Sampling — Indoor Classroom Demonstration — Macroinvertebrate Population Samples

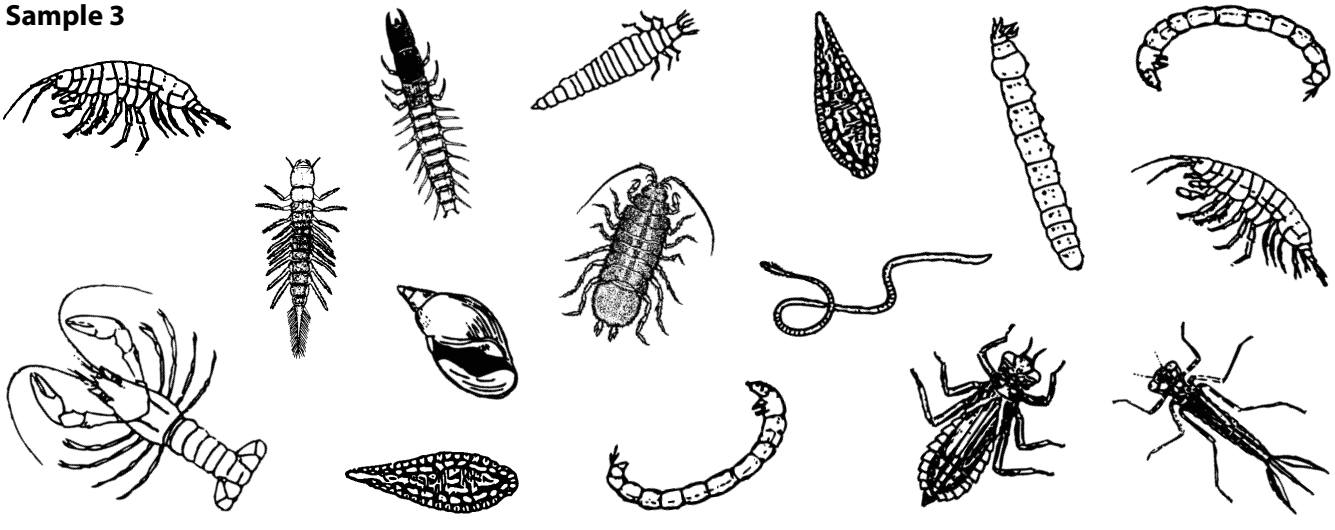
Sample 1



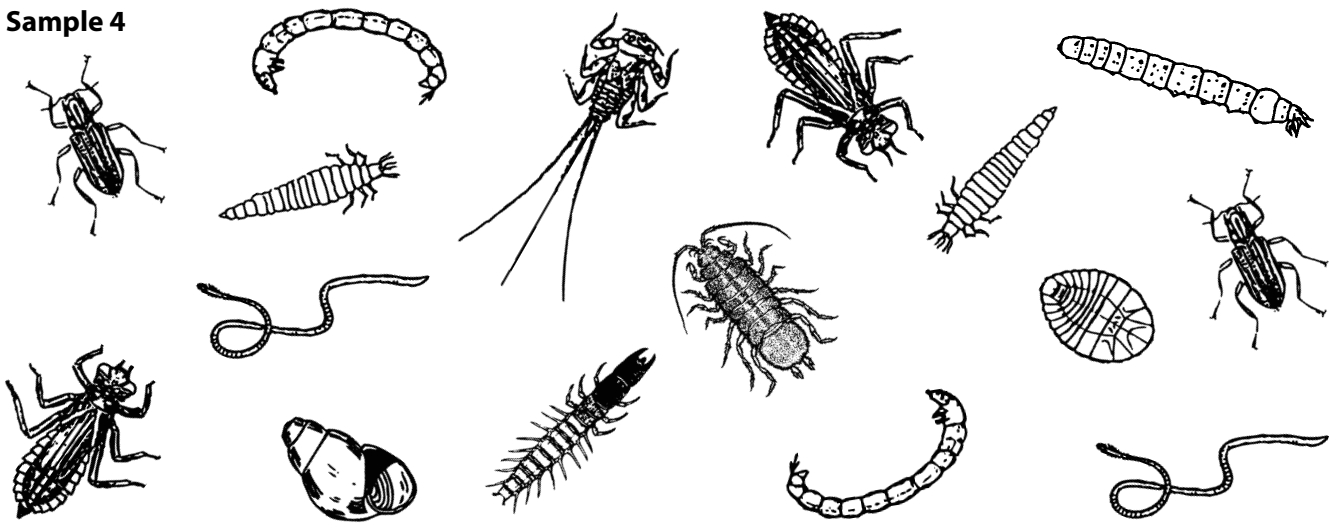
Sample 2



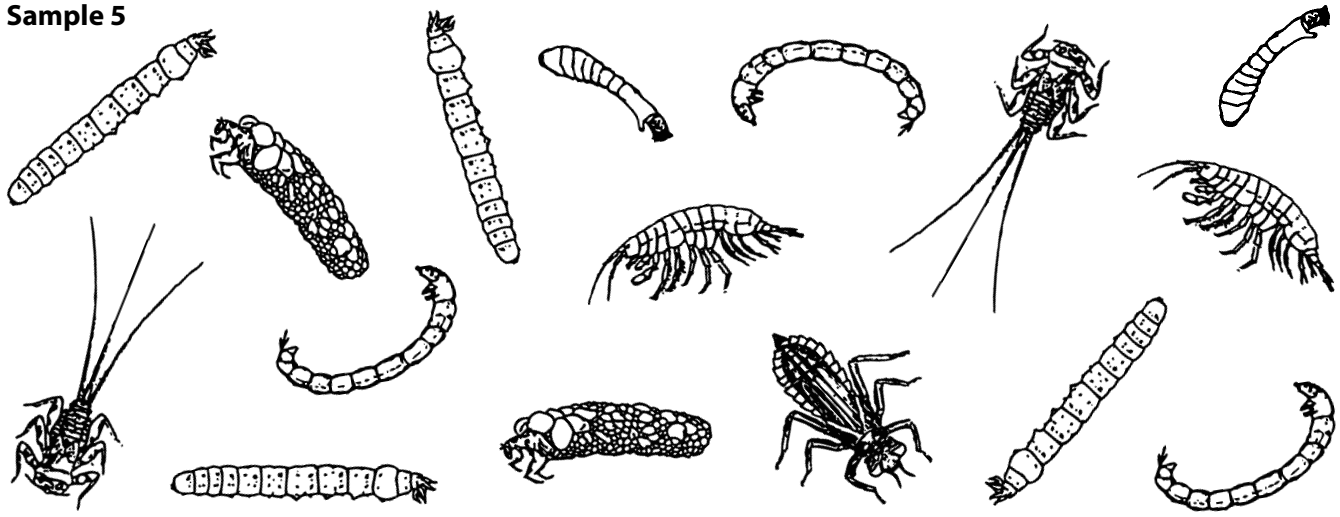
Sample 3



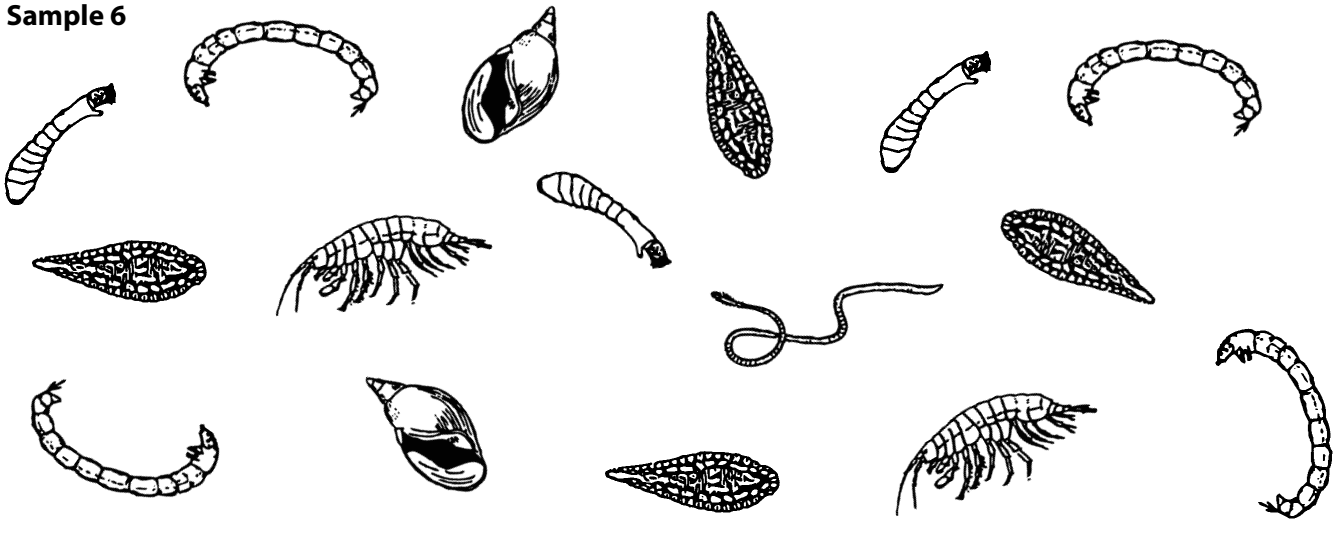
Sample 4



Sample 5



Sample 6



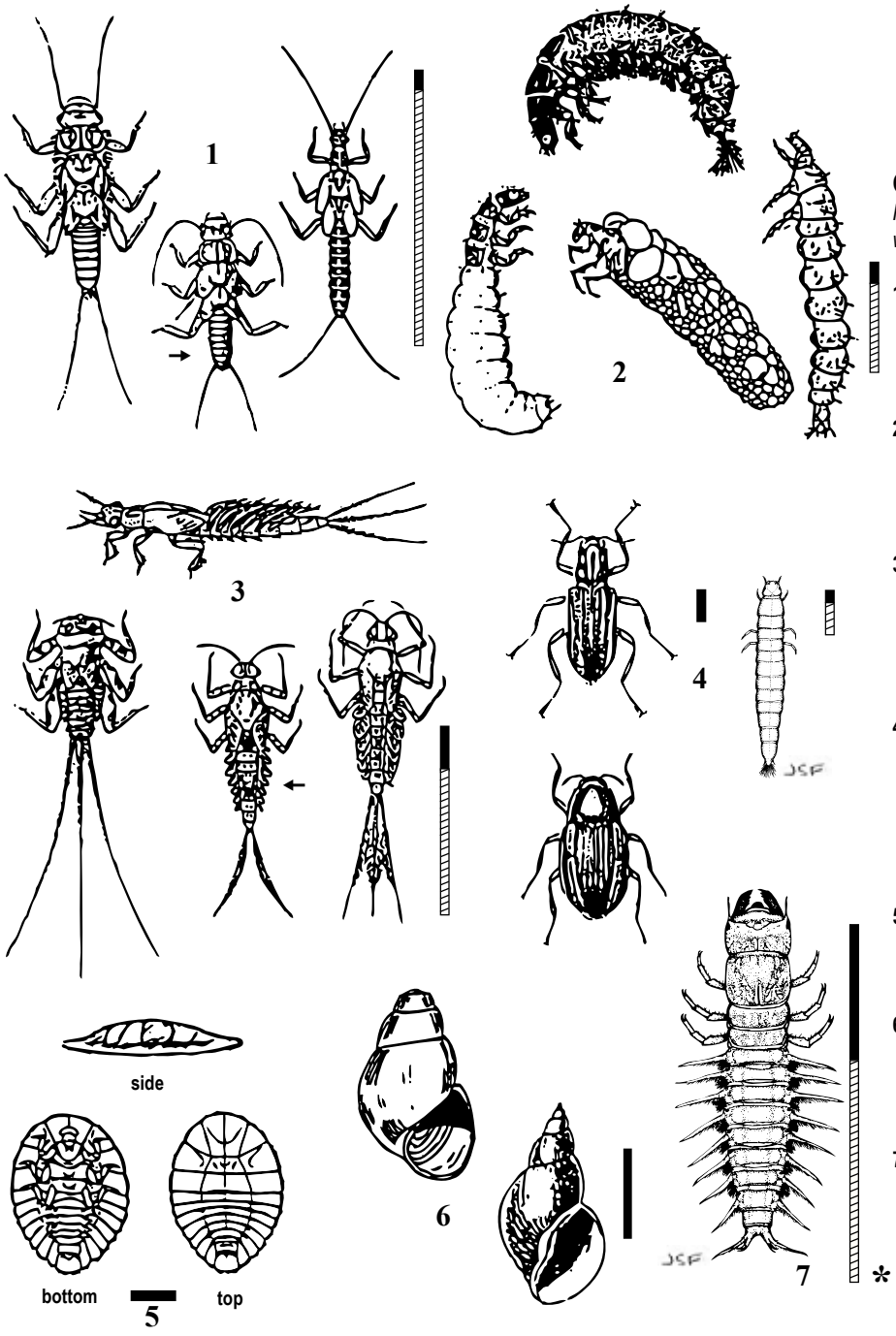
Cleaning and Disinfecting Gear and Equipment Protocol

Due to the potential of spreading pathogens, especially amphibian chytrid fungus and Ranavirus among survey sites, all field gear and equipment should be cleaned and disinfected. These pathogens can easily spread in aquatic environments and can harm or kill many aquatic wildlife species.

Specific equipment should be cleaned between sampling sites. At minimum, any gear and equipment (boots, waders, nets, traps, seines, wetsuits, etc.) that has been in contact with the soil or water should be cleaned and disinfected before, between, and after each wetland (river, pond, pool, etc.) either by use of disinfectant, desiccation, or heat sterilization.

1. Disinfectant Sterilization: The disinfectant of choice is bleach (sodium hypochlorite). Disinfection is easily accomplished by putting 4 ounces of bleach (half cup) in one gallon of clean water and using this solution (3 percent disinfectant solution) to immerse or rinse off all field gear and equipment prior to going to another wetland (river, pond, pool, etc.). Gear and equipment (boots, waders, nets, traps, seines, wetsuits, etc.) should be completely immersed in the disinfectant solution for 15 minutes or completely wetted with a bleach solution around 50 percent if immersing is not possible. For this disinfecting process, a long-handled brush and 5–10 gallon bucket should be considered standard equipment for field investigators. Brush should be used to remove mud, algae, and other debris from boots, waders, etc. Bleach is the disinfectant of choice because it is the least hazardous chemical for disposal, and it is known to decompose rapidly in the environment. It is best to allow the disinfectant solution to air dry on field gear and equipment if possible. If unable to air dry, rinse disinfectant solution with clean water on dry land not in the wetland. The remaining disinfectant solution should be poured on dry land, not in water, when finished.
2. Desiccation Sterilization: Air drying of gear and equipment will also suffice as a preventative for spreading and killing pathogens. Complete air drying, preferably in direct sunlight, at an air temperature of 86 degrees F (30 degrees C) or higher for 4 hours will suffice. Drying, as a strategy to sterilize gear and equipment, would have to be long enough to ensure that all water had evaporated.
3. Heat Sterilization: Gear and equipment soaked in hot water will also eliminate pathogens. Heat sterilization at 160 degrees F (71 degrees C) for 20 minutes or 117 degrees F (47 degrees C) for 30 minutes will eliminate pathogens.

Stream Insects & Crustaceans



GROUP ONE TAXA

Pollution sensitive organisms found in good quality water.

1 Stonefly nymph: *Order Plecoptera.* 1/8" - 1 1/2"; 6 legs with hooked tips; 2 hairlike tails. Smooth (no gills) on abdomen (see arrow). May have gills on thorax under the legs.

2 Caddisfly larva: *Order Trichoptera.* Up to 1"; 6 legs on thorax; 2 hooks at end of abdomen. May be in a stick, rock, or leaf case with its head sticking out. May have fluffy gill tufts on lower half.

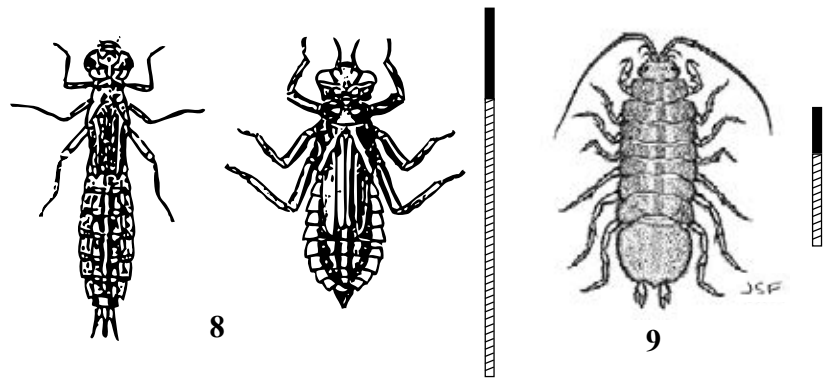
3 Mayfly nymph: *Order Ephemeroptera.* 1/4" - 1"; moving, platelike, or feathery gills on abdomen (see arrow); 6 large hooked legs; antennae; 2 or 3 long, hairlike tails. Tails may be webbed together.

4 Riffle Beetle*: Order Coleoptera.* Adult: Tiny, 6-legged beetle; crawls slowly on the bottom. Larva: Entire length of body covered with hard plates; 6 legs on thorax; uniform brown or black color. Combine number of adults & larvae when reporting total counts.

5 Water Penny larva*: Order Coleoptera.* 1/4"; flat saucer-shaped body, like a penny; segmented with 6 tiny legs underneath. Immature beetle.

6 Gilled Snail: *Class Gastropoda.* Shell opening covered by thin plate called operculum. When pointed up and opening facing you, the shell opens to right. Do not count empty shells.

7 Dobsonfly larva (hellgrammite): *Family Corydalidae.* 3/4" - 4"; dark-colored; 6 legs, large pinching jaws; eight pairs lateral filaments on lower half of body with paired cottonlike gill tufts along underside of lateral filaments; short antennae; 2 pairs of hooks at back end.



GROUP TWO TAXA

Somewhat pollution tolerant organisms can be in good or fair quality water.

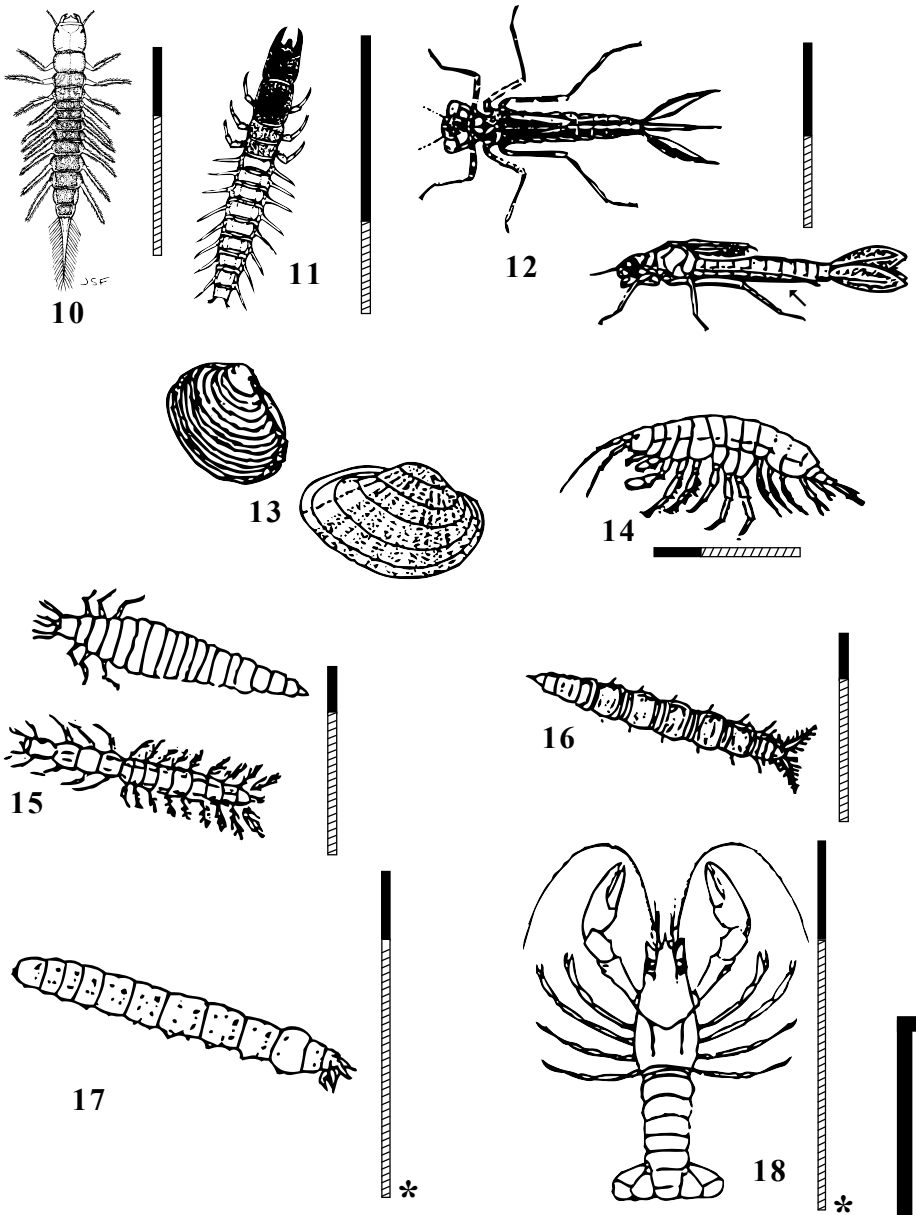
8 Dragonfly nymph: *Suborder Anisoptera.* 1/2" - 2"; large eyes, 6 hooked legs. Wide oval to round abdomen, masklike lower lip.

9 Sowbug: *Order Isopoda.* 1/4" - 3/4"; gray oblong body wider than it is high, more than 6 legs, long antennae, looks like a 'roly poly.'

*** May be larger.**

~Solid bar indicates approx. minimum size. Combined solid and striped bar is approx. maximum size.~

Save Our Streams



GROUP TWO TAXA continued

10 Alderfly larva: *Family Sialidae.* 3/8"- 1"; looks like small hellgrammite but has 1 long, thin, branched tail at end of abdomen (no hooks). No gill tuft underneath the lateral filaments on abdomen.

11 Fishfly larva: *Family Corydalidae.* Up to 1 1/2"; lateral filaments on abdomen. Looks like small hellgrammite but often a lighter reddish-tan color, or with yellowish streaks. No gill tufts underneath.

12 Damselfly nymph: *Suborder Zygoptera.* 1/2"- 1"; large eyes; 6 thin hooked legs; 3 broad oar-shaped tails (gills); body positioned like a tripod. Smooth (no gills) on sides of lower half of body (see arrow).

13 Clam/Mussel: *Class Bivalvia.* Do not count empty shells.

14 Scud: *Order Amphipoda.* 1/4"- 3/4"; white to gray, body higher than it is wide; swims sideways; more than 6 legs; resembles small shrimp.

15 Other Beetle larva: *Order Coleoptera.* 1/4" - 1"; light-colored; 6 legs on upper half of body; feelers; antennae; obvious mouthparts. Diverse group.

16 Watersnipe Fly larva: *Family Athericidae (Atherix).* 1/4" - 1"; pale to green; tapered body; many caterpillar-like legs; conical head; two feathery 'horns' at back end.

17 Crane Fly larva: *Suborder Nematocera.* 1/3" - 4"; milky, green, or light brown; plump caterpillar-like segmented body. May have enlarged lobe or fleshy fingerlike extensions at the end of the abdomen.

18 Crayfish: *Order Decapoda.* Up to 6"; 2 large claws, 8 walking legs, resembles small lobster.

GROUP THREE TAXA

Pollution tolerant organisms can be in any quality of water.

19 Aquatic Worm/Horsehair Worm: *Class Oligochaeta/ Phylum Nematomorpha.* Aquatic worm: 1/4"- 2"; can be very tiny, thin wormlike body. Horsehair Worm: 4"-27"; slender, can be tangled.

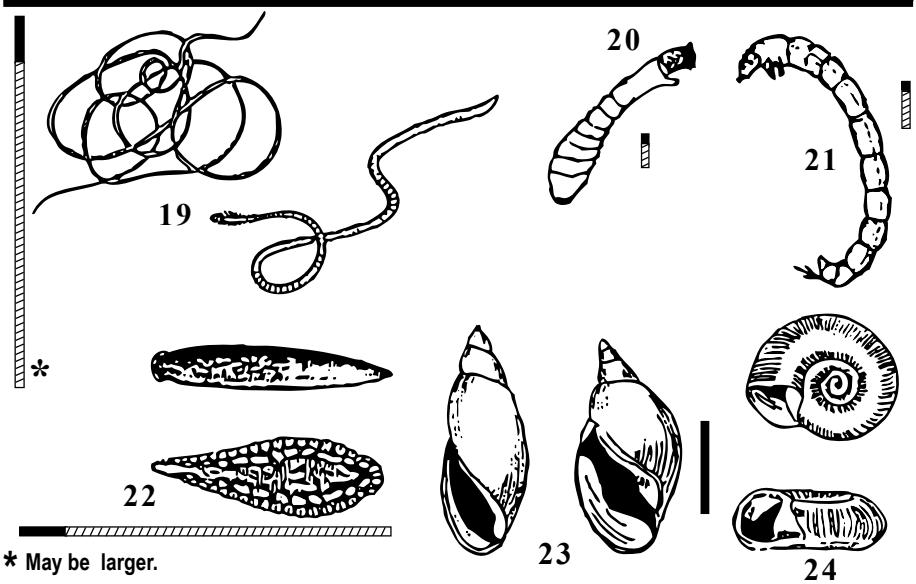
20 Black Fly larva: *Family Simulidae.* 1/8"- 3/8"; one end of body wider. Black head, suction pad on end.

21 Midge Fly larva: *Suborder Nematocera.* Less than 1/4"; distinct head; wormlike segmented body; pair of tiny prolegs under head and tip of abdomen.

22 Leech: *Order Hirudinea.* 1/4" - 6"; flattened muscular body, ends with suction pads.

23 Pouch Snail and Pond Snails: *Class Gastropoda.* No operculum. Breathe air. Shell usually opens on left. Do not count empty shells.

24 Other snails: *Class Gastropoda.* No operculum. Breathe air. Snail shell coils in one plane. Do not count empty shells.



*** May be larger.**

~Solid bar indicates approx. minimum size. Combined solid and striped bar is approx. maximum size.~

MISSOURI STREAM TEAM

01/10
STR 250

6 PEOPLE and the Environment

Estimated Time

(2) 50-minute class periods

Vocabulary

Ecological footprint
Engineering design
Goods
Greenhouse gas
Nonrenewable resources
Renewable resources
Services

Activities

6.1 Using Chemical Tests to Measure Water Quality
6.2 Water Purification Engineering

Missouri Learning Standards

6-8.LS2.C.2 Evaluate benefits and limitations of differing solutions for maintaining an ecosystem.

Next Generation Science Standards

Performance Expectations

(Science and Engineering Practices underlined)
MS-LS2-5 Engaging in argument from evidence. Evaluate competing design solutions for maintaining biodiversity and ecosystem services.

Disciplinary Core Ideas

LS4.D: Biodiversity and Humans

- Changes in biodiversity can influence humans' resources, such as food, energy, and medicines, as well as ecosystem services that humans rely on — for example, water purification and recycling. (MS-LS2-5)

Crosscutting Concepts

Stability and Change

- Small changes in one part of a system might cause large changes in another part. (MS-LS2-5)

Activity 6.1 Using Chemical Tests to Measure Water Quality

Estimated Time

(1) 50-minute class period

Learning Standards

MLS: 6-8.LS2.C2
NGSS: MS-LS2-5

Objectives

Students will be able to:

1. Evaluate characteristics of water using chemicals, equipment, and tests.
2. Evaluate several characteristics or components of water (temperature, dissolved oxygen, pH, nitrates, chlorides, and/or conductivity) that help determine its quality.
3. Compare water quality test results from the schoolyard with normal natural readings.
4. Identify some of the characteristics of the schoolyard that may affect the quality of water in the schoolyard.
5. Explain why water that appears clean may have poor quality for plants, animals, and people.

Teacher Preparation

While a wide variety of water quality testing kits is available, several basic parameters of water (temperature, dissolved oxygen, pH, nitrates, chlorides, and conductivity) may be tested with reasonable accuracy using simple and relatively inexpensive testing kits. Turbidity is another important water quality parameter and is treated by itself in Activity 2.7 as it relates to erosion and water quality. It is not necessary to test all the parameters listed above. Choose to test the parameters for which you have time and equipment to sample. If you aren't familiar with water quality testing kits, please contact your Conservation Education Consultant, who can recommend the best kits to use for your classroom.

Identify places in the schoolyard from which students could collect samples of water for testing. Ideally, students could compare water from a faucet with two other places in the schoolyard like a pond, rain garden, ditch, or stream. Alternatively, the teacher or students could collect water samples from other places.

Materials

- Student science notebooks
- Pencils
- *Water Chemistry Reference Table* (one per group of 5–7 students)
- *Dissolved Oxygen Percent Saturation Sheet* (one per group of 5–7 students)
- Thermometers for measuring air and water temperature
- Containers for collecting water samples
- Water quality test kits that measure temperature, dissolved oxygen, pH, nitrates, chlorides, and/or conductivity (one for each group of 5–7 students)

Procedure

1. Have students complete their science notebook headings, and measure and record outdoor air temperature.
2. Have students collect water from three sources — a faucet and two other places from the schoolyard. Alternatively, the teacher or students could collect water samples from other places and bring them to school. Be sure to collect enough water necessary for testing, according to the instructions of the test kits.
3. Label water samples 1, 2, and 3.
4. Discuss water quality with students.

   Q: What is water quality?
   A: Water quality refers to concentrations of specific chemicals or levels of parameters in water. States are required to adopt water quality criteria that protect aquatic life and human health. In Missouri, minimum standards for water quality are established by the Missouri Clean Water Commission. Missouri's complete Water Quality Standards may be found at **dnr.mo.gov/env/wpp/wqstandards**.

   Q: What are some of the characteristics of water to consider when trying to measure water quality?
   A: Some characteristics or components of water to consider are temperature, dissolved oxygen, pH, nitrates, chlorides, conductivity, and turbidity. Each component may be present in water in high or low amounts. Considered altogether, these amounts can help measure overall water quality in a range from poor to fair, good, and excellent.

5. Have students make observations about physical characteristics of the water samples. Have students record these observations in their science notebooks and include a prediction about whether each sample has good water quality or poor water quality for plants, animals, and people.

   Q: Without using a test kit, what else could you use to make your observations about physical characteristics of water?
   A: Appearance of the water, smell, objects in the water, color, amount of sediment, etc.

6. If students did not collect the samples, have them make predictions about where the water samples came from.
7. Divide students into three groups, assigning each group to test one sample (1, 2, and 3). Each group could be subdivided into two smaller groups.
8. Instruct students to conduct water testing according to the instructions of the test kits.
9. After dissolved oxygen (mg/L) is tested, instruct students to determine dissolved oxygen (D.O.) percent saturation using their D.O. and temperature readings and the *Dissolved Oxygen Percent Saturation Sheet*. D.O. percent saturation determines how much oxygen is available to aquatic organisms.
10. Have students create data charts in their science notebooks and record their test results for the parameters they tested.
11. Instruct students to compare their water quality test results from the schoolyard with normal natural readings using the Water Chemistry Reference Table. Whether or not schoolyard test results fall within the natural readings on the table, discuss some of the characteristics of the schoolyard that may affect the quality of water in the schoolyard.

    Q: What would explain differences in temperature of water in the schoolyard?
    A: Presence or absence of trees and shrubs next to a body of water; amount of suspended solids in the water due to soil erosion; and stormwater runoff from parking lots, sidewalks, or streets that have been warmed from the sun.

    Q: How does water temperature affect dissolved oxygen?
    A: As water temperature increases, its capacity to dissolve oxygen decreases. As water temperature decreases, its capacity to dissolve oxygen increases.

Q: What are some influences in the schoolyard on dissolved oxygen?
A: Water temperature, precipitation, suspended solids, aquatic plants, organic wastes, and runoff.

Q: What are some factors in the schoolyard that can affect pH?
A: Acid rain, pollution, and chemical spills. Alkaline (basic) limestone and dolomite rock is common in most parts of Missouri and can neutralize acidic toxins in acid rain or acid snow before it has a negative impact on the water quality of ponds and streams.

Q: What are some possible sources of nitrates and phosphates in the water in the schoolyard?
A: Fallen leaves and other organic matter that decays; wastewater from leaking septic systems; runoff with pet waste or animal feedlot waste; runoff with fertilizers from pastures, crops, or lawns; detergents.

12. If your water quality test kits included criteria for scoring or ranking results, have students determine the overall quality of the water in their samples.

Q: Were your predictions about the sources of the water samples correct? Why or why not?
A: Answers may vary.

13. If students did not collect the samples, reveal the locations of the three water samples.

Q: Did your predictions of water quality for the three water samples match your test results? Why or why not?
A: Water that appears clean may have poor quality (or may even be dangerous) for plants, animals, and people because many toxins, pollutants, and other water quality impairments cannot be detected by visual inspection or testing for odors.

Q: Is water suitable for wildlife OK for people to drink?
A: No. Though untreated water may appear clean, it may still contain bacteria, heavy metals, and other toxins harmful to people.

Q: Is drinking water suitable habitat for wildlife?
A: No. Municipal drinking water is often treated with chlorine, which is harmful to wildlife.

Wrap-up

Q: Are the parameters of water we tested the only ones that should be considered when measuring water quality?

A: No. These tests can help measure general water quality, but many other factors are important — especially when testing water for human consumption. Water components harmful to people include bacteria, heavy metals, and hormones from prescription drugs. Currently, there are few or no treatment options for many pharmaceuticals in aquatic habitats and drinking water supplies.

Q: What are the consequences of low water quality for plants and animals? For people?

A: High temperatures can speed up metabolism in fish and invertebrates leading to higher exertion and greater energy and oxygen needs. High temperatures can also reduce dissolved oxygen levels. Sensitive aquatic organisms may disappear due to the lack of oxygen needed to fulfill their life cycle. Nutrients cause excessive growth of plants, which decay and draw oxygen at night, drastically reducing dissolved oxygen for aquatic animals to take up. Terrestrial wildlife may suffer health effects from drinking polluted surface waters. Some pollutants bioaccumulate through the food chain, causing developmental and neurological damage to top predators.

Poor water quality affects people by reducing recreational opportunities and making fish less safe to eat. Pollution affects drinking water sources that become more expensive to treat for consumption leading to potential economic and health consequences.

Q: Considering the sources and reasons for poor water quality, what are some things students can do to improve water quality or maintain good water quality in their schoolyard? At their homes, yards, and farms?

A: Students can plant native grasses, forbs, and trees with deep roots to provide shade and also to help filter pollutants that may run off from impervious surfaces such as parking lots, streets, and rooftops. Don't litter, and never put waste of any kind down storm drains, as they lead directly to the nearest stream. Share knowledge with others about why clean water is important to the health of people and wildlife and encourage proper waste disposal and recycling.

Extension: Using a microscope

Use a microscope to examine water samples. Sketch, label, and describe organisms in the science notebook. Using reference materials, identify what can be seen. Are different organisms in different samples? Why? Is there a correlation between the number and type of organisms and water quality? Consider that these organisms are part of aquatic food chains and food webs as well.

Cross-Curricular

Considering the sources and reasons for poor water quality, have students write a persuasive essay to an individual or group in their community who is negatively affecting local water quality.

Dissolved Oxygen Percent Saturation Sheet
D.O. (mg/L)

Temp (C)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0	7%	14%	21%	27%	34%	41%	48%	55%	62%	68%	75%	82%	89%	96%	103%
1	7%	14%	21%	28%	35%	42%	49%	56%	63%	70%	78%	85%	92%	99%	106%
2	7%	14%	22%	29%	36%	43%	51%	58%	65%	72%	80%	87%	94%	101%	109%
3	7%	15%	22%	30%	37%	45%	52%	60%	67%	74%	82%	89%	97%	104%	112%
4	8%	15%	23%	31%	38%	46%	53%	61%	69%	76%	84%	92%	99%	107%	115%
5	8%	16%	24%	31%	39%	47%	55%	63%	71%	78%	86%	94%	102%	110%	118%
6	8%	16%	24%	32%	40%	48%	56%	64%	72%	80%	88%	97%	105%	113%	121%
7	8%	17%	25%	33%	41%	50%	58%	66%	74%	83%	91%	99%	107%	116%	124%
8	8%	17%	25%	34%	42%	51%	59%	68%	76%	85%	93%	101%	110%	118%	127%
9	9%	17%	26%	35%	43%	52%	61%	69%	78%	87%	95%	104%	113%	121%	130%
10	9%	18%	27%	35%	44%	53%	62%	71%	80%	89%	98%	106%	115%	124%	133%
11	9%	18%	27%	36%	45%	54%	64%	73%	82%	91%	100%	109%	118%	127%	136%
12	9%	19%	28%	37%	46%	56%	65%	74%	84%	93%	102%	112%	121%	130%	139%
13	10%	19%	29%	38%	48%	57%	67%	76%	86%	95%	105%	114%	124%	133%	143%
14	10%	19%	29%	39%	49%	58%	68%	78%	87%	97%	107%	117%	126%	136%	146%
15	10%	20%	30%	40%	50%	60%	70%	79%	89%	99%	109%	119%	129%	139%	149%
16	10%	20%	30%	41%	51%	61%	71%	81%	91%	102%	112%	122%	132%	142%	152%
17	10%	21%	31%	41%	52%	62%	73%	83%	93%	104%	114%	124%	135%	145%	155%
18	11%	21%	32%	42%	53%	63%	74%	85%	95%	106%	116%	127%	138%	148%	159%
19	11%	22%	32%	43%	54%	65%	76%	86%	97%	108%	119%	130%	140%	151%	162%
20	11%	22%	33%	44%	55%	66%	77%	88%	99%	110%	121%	132%	143%	154%	165%
21	11%	22%	34%	45%	56%	67%	79%	90%	101%	112%	124%	135%	146%	157%	169%
22	11%	23%	34%	46%	57%	69%	80%	92%	103%	115%	126%	138%	149%	161%	172%
23	12%	23%	35%	47%	58%	70%	82%	93%	105%	117%	129%	140%	152%	164%	175%
24	12%	24%	36%	48%	60%	71%	83%	95%	107%	119%	131%	143%	155%	167%	179%
25	12%	24%	36%	49%	61%	73%	85%	97%	109%	121%	133%	146%	158%	170%	182%
26	12%	25%	37%	49%	62%	74%	87%	99%	111%	124%	136%	148%	161%	173%	185%
27	13%	25%	38%	50%	63%	75%	88%	101%	113%	126%	138%	151%	164%	176%	189%
28	13%	26%	38%	51%	64%	77%	90%	102%	115%	128%	141%	154%	166%	179%	192%
29	13%	26%	39%	52%	65%	78%	91%	104%	117%	130%	143%	156%	169%	183%	196%
30	13%	27%	40%	53%	66%	80%	93%	106%	119%	133%	146%	159%	172%	186%	199%
31	13%	27%	40%	54%	67%	81%	94%	108%	121%	135%	148%	162%	175%	189%	202%
32	14%	27%	41%	55%	69%	82%	96%	110%	124%	137%	151%	165%	179%	192%	206%
33	14%	28%	42%	56%	70%	84%	98%	112%	126%	140%	154%	168%	182%	196%	209%
34	14%	28%	43%	57%	71%	85%	99%	113%	128%	142%	156%	170%	184%	199%	213%
35	14%	29%	43%	58%	72%	87%	101%	115%	130%	144%	159%	173%	188%	202%	216%
36	15%	29%	44%	59%	73%	88%	103%	117%	132%	147%	161%	176%	191%	205%	220%
37	15%	30%	45%	60%	75%	89%	104%	119%	134%	149%	164%	179%	194%	209%	224%
38	15%	30%	45%	61%	76%	91%	106%	121%	136%	151%	166%	182%	197%	212%	227%
39	15%	31%	46%	61%	77%	92%	108%	123%	138%	154%	169%	184%	200%	215%	230%

MISSOURI STREAM TEAM

Water Chemistry Reference Table

Use this table as a guide as you interpret your water quality field data. Remember that each aquatic system is different, so this table is only a guide, not a hard-fast rule!

Water Parameter Tested	What it Measures	Natural Readings	Cautionary Readings (Could Be a Problem)	Possible Sources/ Influences	Remedies
Water Temperature	average amount of heat in the water	0°–34°C (32°–93°F)	▪ above 32°C (90°F) ▪ above 24°C for smallmouth bass/ goggle eye streams (84°C) ▪ above 20°C for trout streams (68°C)	▪ thermal discharges (e.g., industrial, waste water treatment plants) ▪ increased turbidity ▪ solar heat (e.g., loss of shade in riparian areas) ▪ heated runoff from impervious surfaces (e.g., asphalt, concrete)	▪ discharges adhering to limits set in permits/ regulations ▪ increased riparian (stream side) shade ▪ decrease impervious surfaces (i.e., revegetate watershed)
Dissolved Oxygen	amount of oxygen dissolved in the water	**natural readings:** 5–15 mg/L (milligrams per liter) or more than 80 percent dissolved O_2 percent saturation in Ozark streams and more than 60 percent dissolved O_2 percent saturation in prairie streams or streams with no aeration **cautionary readings:** ▪ below 6 mg/L cold water *Standards* violation ▪ below 5 mg/L cool and warm water *Standards* violation ▪ 3–5 mg/L (40–80 percent) causes stress resulting in abnormal feeding, reduced reproduction ▪ < 3 mg/L (<40 percent) results in death in most species ▪ 0 mg/L = anoxic		▪ atmosphere via aeration (e.g., wind, running water) ▪ photosynthesis by algae and other aquatic plants	▪ can control quantity of algae by limiting nutrients (N, P) entering the water ▪ reduce water temperature
pH	acid/base of the water	generally 6.5–9.0	▪ below 6.5 ▪ above 9.0	▪ acid rain ▪ industrial pollution ▪ chemical spills	▪ pollution controls ▪ pH moderation by addition of acid or basic compounds
Nitrates	organic matter or fertilizer materials in water	0.0–2.0 mg/L	consistent readings above 2 mg/L	▪ human sewage ▪ industry output ▪ domestic use of detergents ▪ fertilizer (urban and agricultural) ▪ animal wastes	▪ vegetated riparian zones ▪ limit usage of agricultural and yard fertilizers ▪ properly maintained septic systems
Phosphates	organic matter or fertilizer materials in water	0.0–0.2 mg/L	consistent readings above 0.2 mg/L	▪ animal wastes ▪ fertilizer ▪ domestic use of detergents ▪ industry output	▪ vegetated riparian zones ▪ agricultural waste management ▪ limit use of agriculture and yard fertilizers
Turbidity	clarity of the water	▪ highly variable ▪ measured in Nephelometric Turbidity Units (NTUs)	increasing turbidity measurements in a waterbody over a period of time	▪ sediment, usually from increased surface runoff (e.g., off construction sites, cropland) ▪ excessive algae growth ▪ watercraft traffic	▪ sediment controls ▪ riparian zones to reduce nutrients ▪ watercraft speed limits

MISSOURI STREAM TEAM

Activity 6.2 Water Purification Engineering

Estimated Time

(1) 50-minute class period

Learning Standards

MLS: 6-8.LS2.C.2
NGSS: MS-LS2-5

Objectives

Students will be able to:

1. Design a water purification filter using the engineering design process.
2. Plan, construct, and test a water filter.
3. Evaluate competing design solutions based on performance and other criteria.

Teacher Preparation

In this activity, students will work in groups to design, build, and test a water purification filter. Before doing the activity, students should read "Solutions Through Science (and Engineering)" on Page 43 of the student book. This activity involves water, so you may want to prepare a designated area of the classroom or outdoor area for the students to build and test their water filters. Before class, make enough polluted water solution for each group (approximately 2 liters per group) by making a mixture of the suggested materials listed below.

Materials

- Student science notebooks
- Pencils

For the filters:

- Large clear plastic cups or soda bottles
- Coffee filters
- Rubber bands
- Cotton balls
- Sand
- Large and small rocks
- Activated charcoal
- Aquarium filter media
- Paper towels
- Other materials that can be used to filter water (you may want to have students bring what they can from home as part of the design challenge).
- Scissors
- Utility knife, sharp scissor point, or other pointed objects that can be used for punching holes or making slits in the plastic cups or soda bottles.

For the polluted water solution, use a combination of the items below:

- ➤ Water
- ➤ Tea or coffee grounds
- ➤ Dirt
- ➤ Sand and/or small rocks
- ➤ Vinegar
- ➤ Mineral oil
- ➤ Garden waste
- ➤ Food color

Procedure

1. Divide students into groups of at least 2–5 students.
2. Show students the polluted water solution (if you used vinegar in the solution, have them smell the solution).
3. Explain to the students that they are going to compete as teams to design, build, and test a filter with the goal of making the polluted water solution as clear and as odorless as possible. Explain that they will have a time limit (set by you) and can only use the materials you have provided.
4. Walk the students through the engineering design process before they start working in their groups by referring to Page 43 of their student book. Have students describe, sketch, and plan their designs in their science notebooks according to the steps below.
    - Define the problem.
        - Have students describe the problem.
    - Identify the constraints (time, supplies, etc.).
    - Evaluate different solutions.
        - In this step, students (as individuals or as a group) will draft a plan for a water filter. As a group, students will then decide which filter the group will build. Students may combine several plans to develop a new plan.
    - Implement the best design.
        - Students will build and test their design.
    - Monitor and evaluate their design.
        - Students will observe and record changes in the water appearance and smell. DO NOT let the students drink the water!
        - Students will evaluate their water filter based on their results and make recommendations for changes.

Wrap-up

1. Have each group present the following to the class:
    - Their water filter
    - Their final water sample
    - How they designed their filter
    - What criteria they used to select their design
    - How they would change their filter based on their results

    Q: Is this water suitable to drink?
    A: No. Even though it may look clean, it may still contain bacteria, heavy metals, and toxins that are harmful to people but are colorless and odorless.

2. As a class, evaluate which water filter made polluted water the clearest and most free of odors. This filter is considered the winner.

Extension

Have students consider other criteria for evaluating the water filters. Which filter is the least expensive to make? Which filter is the easiest to make? The smallest? The most durable?

Appendices

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Unit Assessment Strategies

A Note About Using Assessments in This Unit

Nature Unhooked offers four models of assessment for teacher use. Each assessment model is intended for a different purpose or desired outcome. Following the assessment list is a description of the intended purpose and placement of each form of assessment.

Four Models of Student Assessments Used in Nature Unhooked

1. Assessments during activities (listed in Teacher Guide as bold-faced Q&A during procedure or wrap-up portion of each activity)
2. Science notebook to be used as performance assessment (science notebook entry, data organization sheets, and other pages in the science notebook.)
3. End-of-chapter Assessments (to be used as either a formative or chapter summative assessment, found after the end of each chapter)
4. *Nature Unhooked* unit pre- and post-test (summative assessment) (Used as a summative assessment when compared to a benchmark or standard, such as prior to the unit instruction)

Suggested Use of Each Assessment Model

1. **Assessments During Activity**
   The assessments provided by the Q&A are meant to be formative in nature. As a general comprehension check during instruction, each activity in the teacher guide contains a bold-faced Q&A section to be used to guide instruction during that particular lesson and activity. Instruction can be driven by these short interval based, informal assessments during instruction and discussion. Student learning can be monitored during activities with these questions to ensure scaffolding occurs and learner outcomes and foundations are in place for the next activity.
2. **Science Notebook to Be Used as Performance Assessment**
   Activities in each chapter contain science notebook activities and/or corresponding notebook worksheets. These entries or worksheets can provide assessment on student performance in instances where learning is measured by demonstrating a performance skill such as data entry, charting, diagramming, computation, and evaluation. To allow more freedom of expression and to provide a safe place for students to learn through writing without fearing not having the "right" answer, assessment of science notebooks should be formative, rather than summative. Information used in the Project Based Learning component of the unit may also be gathered in the science notebook.
3. **End-of-Chapter Assessments**
   End-of-chapter Assessments can be used as a tool to drive instruction between chapters. The end-of-chapter assessments as well as those at the end of individual lessons are formative in nature to monitor the learning progress and improve student learning and comprehension. Also assessed is student comprehension of:
   - Chapter Objectives
   - Next Generation Science Standards: Disciplinary Core Ideas
   - "Big Ideas," listed in the beginning of each chapter of the student book
4. ***Nature Unhooked* Unit Pre- and Post-test**
   This summative assessment is used to evaluate student learning against a benchmark. Unlike the other assessment models, which are formative in nature, the pre- and post-test model of assessment is meant to serve as a product of benchmark rather than a vehicle of driving instruction during the learning process. Average scores of this test are required if schools receive the *Nature Unhooked* grant for materials or for field experience transportation. The comparison of pre- and post-test scores is used to ensure the relevancy of this curriculum. These scores also serve as a functional benchmark for individual teachers.

End-of-Chapter Assessments

The assessment questions listed on the following pages are only one form of end-of-chapter assessments and certainly do not cover all areas of assessment format and question types. Many assessment models are provided throughout the Teacher Guide to reach depth of knowledge levels and higher order thinking skills. Project Based Learning assessment, science notebook assessment, and student notebook self-assessment and rubrics are also assessment tools used in this unit. The following traditional end-of-chapter quantitative assessments include select response, supply response, and project response question types.

Chapter 1 Assessment: The Structure and Properties of Water

1. Which of the following is a true statement?
   a) Fresh water makes up 97 percent of the Earth's surface.
   b) Water is a simple molecule.
   c) Water is made up of four atoms bonded together.
   d) Water generally makes up a small proportion of an organism's entire body weight.

2. Describe the composition of a water molecule. Include the distinct properties of a water molecule such as shape and what constitutes a water molecule.

_____

_____

_____

_____

_____

3. In the box provided below, draw and label the molecular structure of a water molecule.

4. Name the three states in which water can exist.

_____

_____

_____

5. A molecule such as water, in which the charges aren't evenly distributed, is called a

_____ .

Chapter 2 Assessment: The Incredible Journey

1. In the space below, illustrate in words and/or pictures, what is meant by the phrase "we all live downstream." Description and/or drawing should reflect a cause-and-effect relationship.

2. Describe the differences between point-source and nonpoint source pollution. Provide an example of each.

_____

_____

_____

_____

3. In the space below, diagram the water cycle, including any state changes that occur. In addition to state changes, include the involvement and role of living organisms in this cycle.

4. List the similarities and differences between weathering and erosion.

_____

_____

_____

_____

5. _____ refers to the measurement of how clear a liquid is.

Chapter 3 Assessment: Matter and Energy

1. Which of the following is a true statement regarding producers and consumers?
   a) Producers get energy from the sun and consumers get energy from other organisms.
   b) Herbivores and carnivores are examples of producers.
   c) Consumers grow and reproduce by turning sugars into new cells.
   d) Photosynthesis occurs in the cells of consumers, converting energy from sunlight to power chemical reactions.

2. Food webs show how energy flows among organisms. In the space provided, using words, drawings, or other graphic organizer, draw an example of a food web. Include the roles of scavengers and decomposers. Include the path of energy flow among organisms in the food web by including arrows to show the flow of energy.

3. Describe the differences between, and similarities of food webs and food chains.

_____

_____

_____

_____

_____

_____

4. Energy makes a one-way trip through ecosystems. However, only a small portion of the original energy from the sun passes to each new organism next in the food chain, and energy is lost along the way. Using specific plant, animal, or other organism examples, provide an example of this food chain concept of energy loss.

_____

_____

_____

_____

_____

5. The more links that are present in a food chain lessens the amount of energy available for the final consumer in the chain. Which statement best illustrates the consequences of this fact?

a) In nearly every ecosystem, there are more herbivores than plants.
b) In nearly every ecosystem, there more herbivores than carnivores.
c) Ecosystems need a higher proportion of top-level predators.
d) Energy is found in unlimited quantities in nearly all ecosystems.

Chapter 4 Assessment: Interactions

1. Identify an example of an adaptation that supports successful survival and reproduction by choosing the true statement below.
    a) Many plants, such as blackberries, have thorns to attract plant-eating animals to the plant's foliage.
    b) Warning colorations, such as a skunk's stripe, are specialized structures that help animals avoid being eaten.
    c) Camouflage makes prey more easily seen by predators in the environment.
    d) A great blue heron's long neck and daggerlike beak is a specialized structure that generally makes catching prey more difficult.

2. Provide an example of how interactions between different organisms in an ecosystem can shape the numbers and kinds of organisms in that ecosystem. Include organism names and the type of interaction occurring between them and how this shapes the growth, survival, and/or reproduction of each.

_____

_____

_____

_____

_____

_____

3. Which of the following statements regarding interactions between organisms is false?
    a) Competition occurs when two or more organisms try to use the same limited resource.
    b) Exploitation refers to interactions that benefit one organism while harming, weakening, or killing the other organism.
    c) Mutualism is a type of interaction that benefits only one organism in an interaction.
    d) The competitive exclusion principle predicts that if two species compete for the same set of resources in the same place, one species will become more competitive and successful at attaining those resources.

4. The number of individuals in a population that a given area can support at any given time is called its

_____ .

5. Interactions between organisms shape the numbers and kinds of organisms found in an ecosystem. Provide an example of interactions between humans and organisms that represent this concept. Include the type of interaction, organisms involved, and how that interaction affected the numbers of and kinds of organisms in the ecosystem as a result.

_____

_____

_____

_____

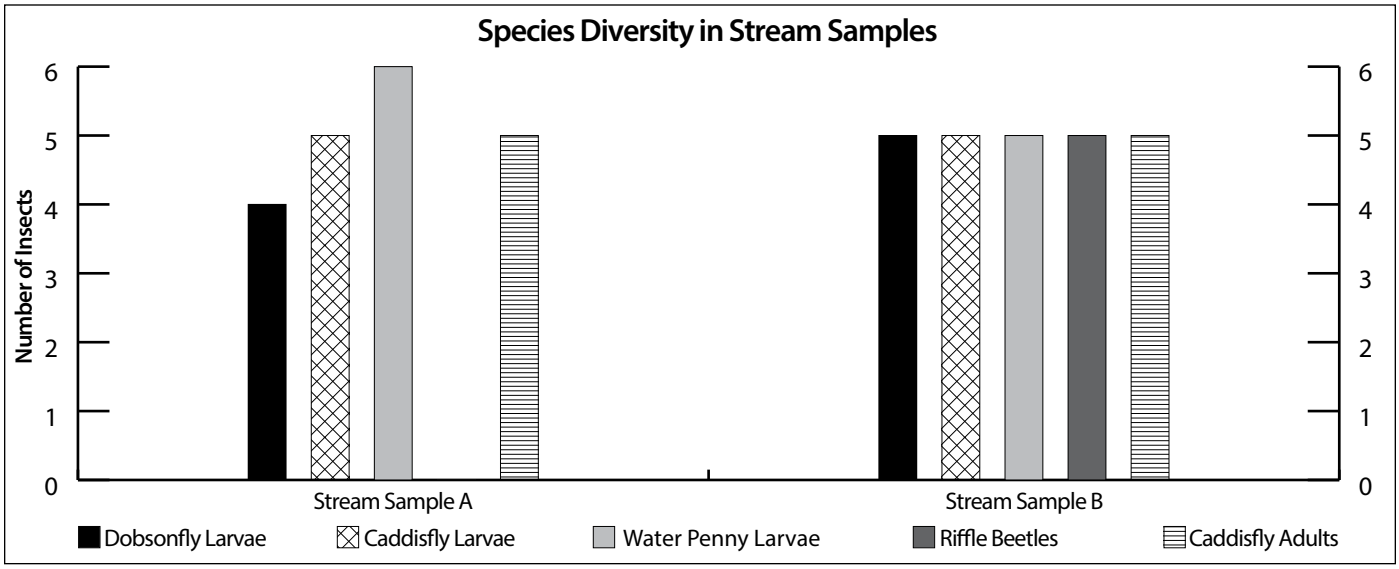
_____

_____

Chapter 5 Assessment: Biodiversity

1. Diversity is affected by species richness and relative abundance. Analyze and interpret the following data of two stream samples.

Which stream sample represents greater species diversity? Provide an argument for your answer by discussing species abundance versus species evenness. In Sample A, which species is more abundant? Which sample displays species evenness?



_____

_____

_____

_____

_____

_____

2. Biodiversity refers to the number of _____,

_____, or _____ in a given area.

3. Biodiversity offers clues to an ecosystem's _____.

4. In an ecosystem with poor biodiversity, a shortage or disappearance of one species may have a _____ effect upon other species in the ecosystem.

   a) positive
   b) short-term
   c) minimal
   d) dramatic

5. List three factors that could threaten the biodiversity in an ecosystem and provide an example of each.

_____

_____

_____

_____

_____

_____

Chapter 6 Assessment: People and the Environment

1. Explain how healthy ecosystems provide goods and services to people and other organisms, and provide an example of both. How does population growth affect the use of ecosystems goods or services?

2. Which of the following is a false statement?
   a) Wetlands curb erosion.
   b) Wetlands control floods.
   c) Wetlands are affected by ecological footprints.
   d) Over the past century, the number of wetlands has increased as the human population decreases.

3. Explain the difference between renewable and nonrenewable resources. Provide an example of each.

4. Describe two ways in which harnessing science, engineering, and/or technology can conserve, improve, or rebuild healthy ecosystems.

5. In the box below, create a sample "Eco-Footprint Diary," in which you record your water usage (in liters) over a 24-hour period on an average day. How many total liters were used in your sample 24-hour period, and how could this number be reduced?

_____

_____

_____

_____

_____

_____

Note: Use the following average measurements in liters per activity.

water bottles: 1 liter toilet flush: 25 liters laundry usage: 100 liters/load dishwasher: 20 liters/load

Unit Pre- and Post-test

1. Water covers approximately how much of the Earth's surface?
    a. 70%
    b. 30%
    c. 90%
    d. 2%
2. Water is a simple molecule made up of
    a. 2 hydrogen atoms and 3 oxygen atoms
    b. 2 hydrogen atoms and 1 oxygen atom
    c. 1 hydrogen atom and 1 oxygen atom
    d. entirely made of hydrogen
3. The change of state from a liquid to a gas that occurs when sunlight turns water into vapor is called
    a. transpiration
    b. evaporation
    c. precipitation
    d. infiltration
4. When water molecules condense on microscopic particles, such as dust specks and the molecules group together gaining enough mass to be pulled down by gravity, the process is called
    a. precipitation
    b. evaporation
    c. crystallization
    d. condensation
5. Water channels and all the land that drains into them are known as
    a. tributaries
    b. watersheds
    c. wetlands
    d. aquifers
6. Producers receive energy from
    a. the sun
    b. other organisms
    c. herbivores
    d. carnivores
7. Consumers
    a. receive energy from the sun
    b. receive energy from other organisms
    c. do not require energy
    d. have internal sources of energy
8. _____ occurs when two or more organisms try to use the same limited resource.
    a. exploitation
    b. competition
    c. mutualism
    d. resource partitioning
9. _____ is a type of interaction in which both organisms benefit.
    a. exploitation
    b. competition
    c. mutualism
    d. parasitism
10. The type of specialized structure or adaptation that a prey organism may have to help it avoid being eaten is called a
    a. limiting factor
    b. warning coloration
    c. resource partitioning
    d. parasite
11. As animal populations grow, competition for resources becomes fierce, causing many individuals of that species to perish. The population then stops growing and is said to have reached
    a. limiting factors
    b. competitive exclusion principal
    c. carrying capacity
    d. ecological community
12. A group of populations living in the same place at the same time is called (a)
    a. biological community
    b. species richness
    c. relative abundance
    d. habitat fragmentation
13. When a species is hunted or fished to or near the point of extinction, this is an example of
    a. habitat fragmentation
    b. habitat destruction
    c. overharvest
    d. a bioblitz
14. Coal and oil are examples of
    a. renewable resources
    b. nonrenewable resources
    c. ecological footprints
    d. greenhouse gases
15. As human populations grow, their use of ecosystem goods and services
    a. increases
    b. decreases
    c. stays the same
    d. has no effect on the environment

Unit Pre- and Post-test: Answer Key

1. Water covers approximately how much of the Earth's surface?
   - ✓ a. 70%
   - b. 30%
   - c. 90%
   - d. 2%

2. Water is a simple molecule made up of
   - a. 2 hydrogen atoms and 3 oxygen atoms
   - ✓ b. 2 hydrogen atoms and 1 oxygen atom
   - c. 1 hydrogen atom and 1 oxygen atom
   - d. entirely made of hydrogen

3. The change of state from a liquid to a gas that occurs when sunlight turns water into vapor is called
   - a. transpiration
   - ✓ b. evaporation
   - c. precipitation
   - d. infiltration

4. When water molecules condense on microscopic particles, such as dust specks and the molecules group together gaining enough mass to be pulled down by gravity, the process is called
   - ✓ a. precipitation
   - b. evaporation
   - c. crystallization
   - d. condensation

5. Water channels and all the land that drains into them are known as
   - a. tributaries
   - ✓ b. watersheds
   - c. wetlands
   - d. aquifers

6. Producers receive energy from
   - ✓ a. the sun
   - b. other organisms
   - c. herbivores
   - d. carnivores

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   - ✓ b. receive energy from other organisms
   - c. do not require energy
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   - ✓ b. competition
   - c. mutualism
   - d. resource partitioning

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   - a. exploitation
   - b. competition
   - ✓ c. mutualism
   - d. parasitism

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    - c. resource partitioning
    - d. parasite

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    - a. limiting factors
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    - ✓ c. carrying capacity
    - d. ecological community

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    - c. relative abundance
    - d. habitat fragmentation

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    - b. habitat destruction
    - ✓ c. overharvest
    - d. a bioblitz

14. Coal and oil are examples of
    - a. renewable resources
    - ✓ b. nonrenewable resources
    - c. ecological footprints
    - d. greenhouse gases

15. As human populations grow, their use of ecosystem goods and services
    - ✓ a. increases
    - b. decreases
    - c. stays the same
    - d. has no effect on the environment

Unhooked in Action — Project Based Learning Guide Sheets

The following student pages are guide sheets that may be used with the *Unhooked in Action* Project Based Learning component of *Nature Unhooked*.

- Possible Solution Criteria Master Guide
- Current Event Guide
- School and Community Venn Diagram
- What Do We Know?
- Mapping Solutions Guide
- Possible Solution Criteria Guides (copies for multiple solutions)
- Solution Evaluation Guide
- Persuasive Argument Guide
- Project Scope Guide (3 pages)
- Project Calendar

Possible Solution Criteria Master Guide

Materials and Equipment

These are the materials and equipment that are currently available:

Time

This is the amount of time you have for

- Planning _____
- Preparation _____
- Implementing the project _____
- Presenting the project _____

Total number of hours: _____

Money

This is the amount of money we have for this project:

Is fundraising an option? **Y** or **N**

Can you ask for donations of materials or money? **Y** or **N**

Off-site Visits (Special Considerations)

Is travel authorized? **Y** or **N**

You are allowed _____ off-site visits

You will need to allow for _____ days/weeks to arrange for a bus.

You will need to request permission from

- Parents/Guardians
- School Principal

School and Community Resources

You can recruit volunteer labor: **Y** or **N**

Some experts and community members whom you can contact for advice or guidance:

Permission and Approval

This will vary depending on the project. Please consult with your teacher as to who will need to approve or give permission for you to conduct your project.

Current Event Guide

1. Conduct a search for a news article regarding water issues in your community. Examples of water issues include erosion, water pollution, water shortage, stormwater runoff, flooding, filtering of water, wastewater treatment, outdated infrastructure, drought, etc.
2. Answer the following questions.

Title of Article
News Source
Author
Date of Article
Web Link
Date webpage was visited by you

What was the main topic of the article?

Summarize the important points mentioned in the article. Be sure to include any solutions to the problem mentioned in the article.

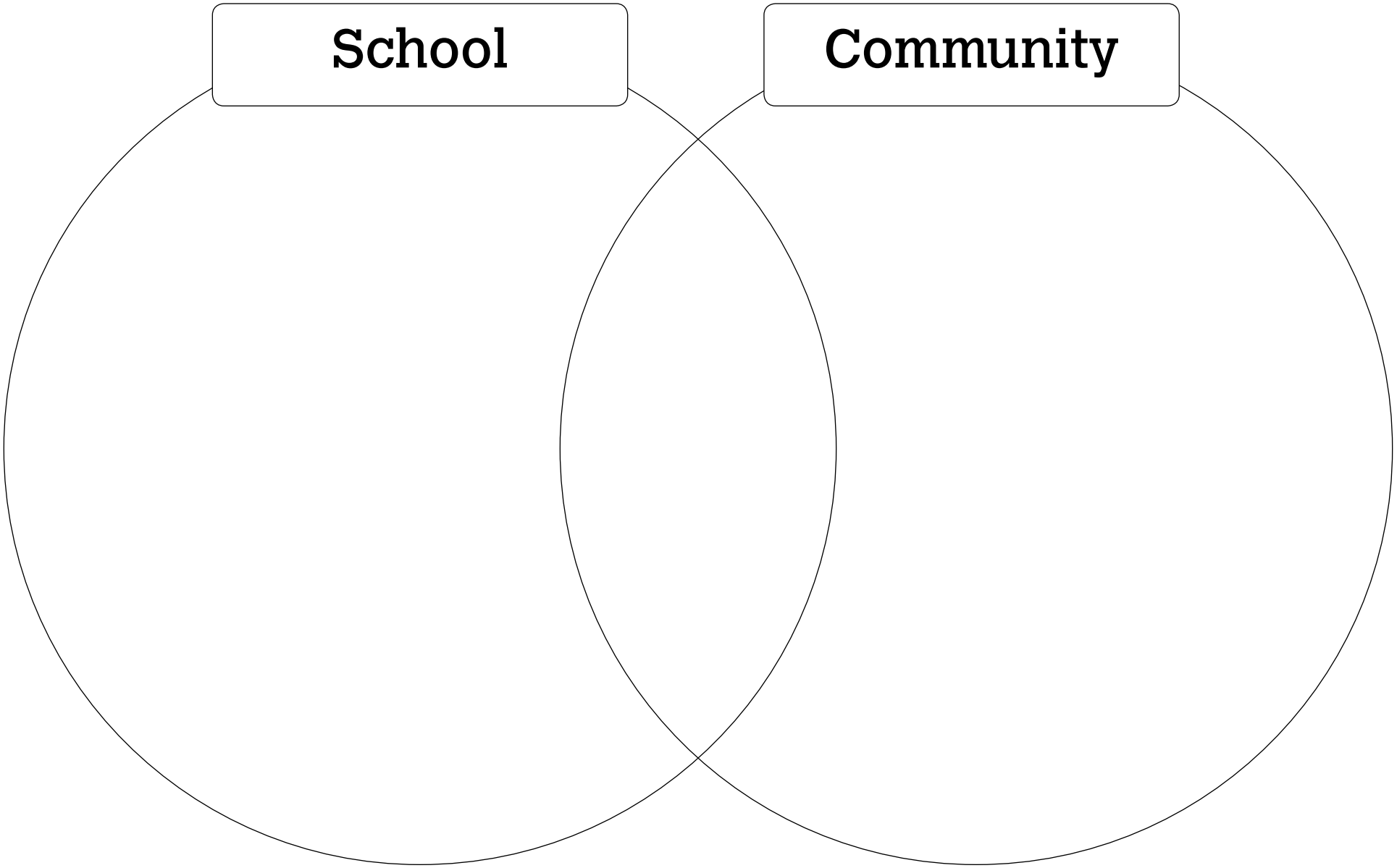
Do the problems mentioned in the article impact or affect your **community**? How?

Do the problems mentioned in the article impact or affect your **school**? How?

Do the problems mentioned in the article impact or affect **you**? How?

School and Community Venn Diagram

Compare the water issues in your school with the water issues in your community. Are there any issues that overlap (apply to both the school and the community)?



What Do We Know?

1. What do we know about the water issues in our school or community?	2. How might this issue impact the environment and/or biodiversity?	3. How might this issue impact students, our families, and our community?

Mapping Solutions Guide

1. Choose one issue to address.
2. List the root causes of the issue.
3. Brainstorm three possible solutions to the issue.

The Issue

Root Causes of the Issue

Possible Solution 1

Possible Solution 2

Possible Solution 3

Possible Solution Criteria Guide 1

Issue

Possible Solution 1

Materials and Equipment

What materials or equipment is needed to complete this project? Note if the materials or equipment is available or if it must be purchased or rented.

Time

How much time do you need for

- Planning _____
- Preparation _____
- Implementing the project _____
- Presenting the project _____

Total number of hours: _____

Money

How much money will you need to complete this project?

How much money do you have currently?

How much money do you need to raise?

Off-site Visits (Special Considerations)

Is travel required?

Do you need transportation?

School and Community Resources

Do you need volunteer labor?

Do you need to consult an expert for advice or guidance? If so, who?

Do you need to reach out to community leaders or other organizations? If so, who?

Permission and Approval

Who will need to approve your project? (Examples: teacher, school board, or city council)

Do you need any permits to implement this project?

Possible Solution Criteria Guide 2

Issue

Possible Solution 2

Materials and Equipment

What materials or equipment is needed to complete this project? Note if the materials or equipment is available or if it must be purchased or rented.

Time

How much time do you need for

- Planning _____
- Preparation _____
- Implementing the project _____
- Presenting the project _____

Total number of hours: _____

Money

How much money will you need to complete this project?

How much money do you have currently?

How much money do you need to raise?

Off-site Visits (Special Considerations)

Is travel required?

Do you need transportation?

School and Community Resources

Do you need volunteer labor?

Do you need to consult an expert for advice or guidance? If so, who?

Do you need to reach out to community leaders or other organizations? If so, who?

Permission and Approval

Who will need to approve your project? (Examples: teacher, school board, or city council)

Do you need any permits to implement this project?

Possible Solution Criteria Guide 3

Issue

Possible Solution 3

Materials and Equipment

What materials or equipment is needed to complete this project? Note if the materials or equipment is available or if it must be purchased or rented.

Time

How much time do you need for

- Planning _____
- Preparation _____
- Implementing the project _____
- Presenting the project _____

Total number of hours: _____

Money

How much money will you need to complete this project?

How much money do you have currently?

How much money do you need to raise?

Off-site Visits (Special Considerations)

Is travel required?

Do you need transportation?

School and Community Resources

Do you need volunteer labor?

Do you need to consult an expert for advice or guidance? If so, who?

Do you need to reach out to community leaders or other organizations? If so, who?

Permission and Approval

Who will need to approve your project? (Examples: teacher, school board, or city council)

Do you need any permits to implement this project?

Possible Solution Criteria Guide — Additional Solutions

Issue

Possible Solution No. _____

Materials and Equipment

What materials or equipment is needed to complete this project? Note if the materials or equipment is available or if it must be purchased or rented.

Time

How much time do you need for

- Planning _____
- Preparation _____
- Implementing the project _____
- Presenting the project _____

Total number of hours: _____

Money

How much money will you need to complete this project?

How much money do you have currently?

How much money do you need to raise?

Off-site Visits (Special Considerations)

Is travel required?

Do you need transportation?

School and Community Resources

Do you need volunteer labor?

Do you need to consult an expert for advice or guidance? If so, who?

Do you need to reach out to community leaders or other organizations? If so, who?

Permission and Approval

Who will need to approve your project? (Examples: teacher, school board, or city council)

Do you need any permits to implement this project?

Solution Evaluation Guide

Possible Solution No. 1

Do you have all materials? **Y** or **N**

Do you have all equipment? **Y** or **N**

Do you have enough time? **Y** or **N**

Do you have enough money? **Y** or **N**

Do you have enough school and community resources? **Y** or **N**

Do you have permission/approval? **Y** or **N**

Total number of **Y**:

Total number of **N**:

What are the special considerations for this solution? For example, "off-site visits are required" or "fundraising will be necessary."

Rank this solution. Use a scale of 1 to 3 where 1 = most feasible and 3 = least feasible.

Possible Solution No. 2

Do you have all materials? **Y** or **N**

Do you have all equipment? **Y** or **N**

Do you have enough time? **Y** or **N**

Do you have enough money? **Y** or **N**

Do you have enough school and community resources? **Y** or **N**

Do you have permission/approval? **Y** or **N**

Total number of **Y**:

Total number of **N**:

What are the special considerations for this solution? For example, "off-site visits are required" or "fundraising will be necessary."

Rank this solution. Use a scale of 1 to 3 where 1 = most feasible and 3 = least feasible.

Possible Solution No. 3

Do you have all materials? **Y** or **N**

Do you have all equipment? **Y** or **N**

Do you have enough time? **Y** or **N**

Do you have enough money? **Y** or **N**

Do you have enough school and community resources? **Y** or **N**

Do you have permission/approval? **Y** or **N**

Total number of **Y**:

Total number of **N**:

What are the special considerations for this solution? For example, "off-site visits are required" or "fundraising will be necessary."

Rank this solution. Use a scale of 1 to 3 where 1 = most feasible and 3 = least feasible.

Persuasive Argument Guide

Define the problem

Explain the solution

Claims as to why this solution is best

Evidence based on criteria outlined in the *Solution Evaluation Guide*

Persuasive statement on why this problem and solution should be adopted for the class project

Project Scope Guide

Project Title

Timeline

Project design is due on _____ Other important dates:

Implementation phase is from _____ to _____

Presentations are due on _____

Materials and Equipment

List all materials and equipment needed to complete the project.

Money

Money required to complete the project:

Money available:

Money that must be raised:

List donations needed:

Special Considerations

List any special considerations, such as permission for off-site visits, volunteers, or training needed:

Project Purpose

What is it that you want to accomplish, and why do you want to do it? Restate the problem in your answer.

Project Goals

Goals are measurable outcomes that should be specific, measurable, agreed upon, realistic, and time-bound (SMART).

Action Steps

For each goal, list each step that must be completed in order to achieve the goal. Number each step in a logical sequence. Assign each step to a student(s) and add their name next to the step. Include a date due for each step. You will need one sheet for each goal.

Goal No. _____

List steps to complete the goal. Include the person(s) responsible and the date each action is due. Use the *Project Calendar* to track and monitor the progress.

Project Calendar

Month:						
Sunday	**Monday**	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**

Field Experience

The purpose of providing a field experience connected with *Nature Unhooked* is for students to demonstrate and apply skills and knowledge gained from the activities from this unit in authentic settings. The field experience may be held at the end of the unit as a culminating application of what students learned, or the experience may be used to gain insight and collect data for the *Unhooked in Action* project. Whenever the field experience is held, it should tie in with the curriculum and support student learning. For this reason, this opportunity is distinguished from traditional school "field trips."

The goal is to have students engaged in active field studies related to the curriculum. Field studies should consist of student-centered, collaborative, experiential investigations, applying science practices rather than consisting of tours, demonstrations, or indoor nature presentations. During the field experience, students should have their science notebooks with them. Students should clearly understand the purpose of the science notebooks, which data are to be collected and how, and what they will be doing with the data when they return to school.

Successful field experiences require careful planning and preparation. This includes selection of dates and locations, transportation arrangements, having supplies and equipment, selection of activities, and preparation of the students and adult support. Conservation Education Consultants may provide valuable assistance in the details of planning and implementing field experiences and other conservation education efforts.

Setting a Date

Determine a program date at least four months in advance. For a spring field experience, make arrangements in the fall; for a fall field experience, in the spring. Consider identifying potential alternative dates in case inclement weather causes a cancellation.

Selecting a Site

Choose a location with an aquatic feature, such as a stream, lake, or wetland (for example, a conservation area, state park, or national forest). Many sites require reservations and possibly special use permits. Site managers may be able to provide important information about site conditions, available facilities, and other pertinent information. It is strongly recommended that you become familiar with the site, making at least one visit to the site prior to the date of your field experience.

Getting Help

Having knowledgeable help is essential. Recruit responsible adult volunteers who enjoy being outdoors. One volunteer for every 5–10 students is ideal. Provide a copy of the day's activity schedule and other pertinent information to all volunteers. Be sure they know what is expected of the students and that their role is to facilitate and keep the students engaged. It may be helpful to meet with adult volunteers in advance of the field experience day to review expectations.

To help ensure that the field experience day runs smoothly, volunteers should serve as activity facilitators, station leaders, or group guides. The role of the facilitator is to keep the students on task, be aware of safety concerns, and keep the students on schedule. If field study stations are established, facilitators should stay at their stations during the entire event for each group that comes to them. If other adult volunteers are available, they may serve as chaperons to stay with each group and accompany them to each activity station.

Arranging Transportation

Contact the school district's transportation service to secure buses for your desired date per your district's procedures. Ask for a cost estimate for the bus mileage and the driver. Requesting that buses remain on site for the duration of the field experience ensures availability of shelter during inclement weather and emergency transportation if needed. Be prepared to provide a map or directions for the bus driver(s) as well as for adult volunteers who are driving separately.

Planning for Emergencies

Compile a list of all students participating in the experience, and provide a copy to the school office per your district's procedures. Let your principal know where the students are going, what they will be doing, and when to expect your return. Have a way to contact the school should an emergency arise. (Check cell phone reception at the location.) Have a plan in case of sudden changes in weather, such as thunderstorms. Do not seek shelter around water or under trees in lightning storms. In case of severe weather, the bus may be used as a shelter. Plan to have the bus and driver remain in the immediate vicinity during the entire event. Make sure first-aid kits are available. Other safety considerations include

- Students should use personal protection equipment such as disposable gloves and safety goggles when conducting chemistry tests.
- Be aware of environmental hazards such as poisonous plants, stinging and biting insects, and hazardous terrain.
- Ensure that students are properly dressed for weather conditions, including use of sunscreen.
- Require students to handle equipment safely and responsibly, especially potential hazards such as fishhooks.

Selecting Activities and Stations

Establishing a rotation of field study stations is one method to keep student groups small and more manageable. Teachers have many activity options to include in a rotation schedule. Which activities are chosen will depend on resources available, time constraints, number of adult volunteers, student interests, and activities related to the *Unhooked in Action* project or other curriculum objectives. Activities from the unit that lend themselves well to the *Nature Unhooked* field experience include

- *2.3 — Water Evidence Hike*
- *2.7 — Turbidity*
- *4.4 — Fishing for Specialized Structures*
- *5.2 — Aquatic Invertebrate Sampling*
- *6.1 — Using Chemical Tests to Measure Water Quality*

These activities are best conducted by students working in small groups rotating through activity stations. Allow at least 30 minutes per station including rotation time. If you have more than 100 students, spread the trip over multiple days with no more than 100 students going each day, or consider doubling the stations if sufficient resources and personnel allow.

To prepare for the field experience, have students consider the environmental factors of the place you will visit, including the watershed, bodies of water, and plants and animals in that ecosystem. You may have them prepare maps or conduct some specific research prior to their field experience. Ask students to make inferences about the ecological health of the place you will visit. During the field experience and through these field study stations, students may apply authentic science practices from which observations are made, research is conducted, and conclusions are drawn. Through this experience, students may gain a better appreciation and understanding of aquatic resources and ecosystems.

Below is a sample 6-group, 4-station rotation schedule that can be used with a group of 75 students.

		Time Slot								
	Field Study Activity	8:45-9:00	9:00-9:30	9:30-10:00	10:00-10:30	10:30-11:00	11:00-11:30	11:30-12:00	12:00-12:30	12:30-1:00
1	Fish Sampling (*Activity 4.4*)	Arrival and Orientation	Groups ABC			Lunch Break	Groups DEF			Clean Up Wrap-up Load Buses Depart
2	Invertebrate Sampling (*Activity 5.2*)		D	F	E		A	C	B	
3	Water Chemistry (*Activities 2.7 and 6.1*)		E	D	F		B	A	C	
4	Watershed Hike (*Activity 2.3*)		F	E	D		C	B	A	

The field experience should be followed by discussion and reflection on subsequent days back at school. Sound science includes communication of one's discoveries. Data can be better organized, reviewed, and discussed. There may be a wrap-up activity, such as creating an official report or class field guide based on observations of the field study location. The field experience may also be part of the Project Based Learning approach.



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